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PHYTOPLANKTON ORGANISMS OF THE ARABIAN SEA OFF THE WEST COAST OF INDIA*

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Applied aspects of marine fisheries research have considerably suffered in India owing to the lack of a proper taxonomical appraisal of the minute plant organisms occurring in the water which are the prime synthesizers of all food matter in the sea and also form the food of a large number of small animals, important links in the food chain, and of some fishes of commercial importance. An account for the Diatoms (Bacillariophyceæ), one class of the algal organisms, was published by the writer in 1946 with descriptions and figures of over 170 forms, from the east coast of India. With the inauguration of the Central Marine Fisheries Research Station, opportunity was available to continue the studies on the Bacillariophyceæ as well as other phytoplankton organisms, the Dinophyceæ, Myxophyceæ, Silicoflagellatæ, Coccolithineæ and so on. Work was also taken up with reference to their ecology, quantitative abundance over the seasons, magnitude of production of matter by them and the factors responsible for the production, in addition to a taxonomical study. Accounts of these studies are under preparation and will be published later. In this note the organisms recorded during the course of a five years' study are listed.

The diatoms with 226 species constitute the major portion of the phytoplankton as regards variety and bulk of occurrence; the Dinophyceæ come next with 121 forms and except for *Noctiluca miliaris* Suriray, none of the other species contribute to the bulk generally, though some species at certain times occur in such large quantities as to discolour the sea-water, *e.g.*, *Ornithocercus magnificus* and *Gymnodinium* sp. Species of *Trichodesmium* (Myxophyceæ) occur in large quantities at certain times floating on the surface of the water, while the Chloromonadineæ, *Hornellia marina*, occurs in enormous numbers

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to discolour the water green and causes mortality of fishes often (Subrahmanyan, 1954 *b*). The Euglenineæ, *Protoeuglena noctilucæ* is found in large numbers inside *Noctiluca* and when this *Noctiluca* occurs in swarms, the water is coloured green (Subrahmanyan, 1954 *a*). The species of the remaining classes of algæ are sparsely represented.

Many of the Bacillariophyceæ recorded here, about 150 species of them, have been found on the east coast also (Subrahmanyan, 1946). Over 90% of the total number of species of all other classes listed here are new records for the country.

A few of the important references used in the identification of the species may be cited here: Hustedt (1930–32), Cleve-Euler (1951–55), Schmidt's Atlas (1874–1928) and Subrahmanyan (1946) for the Bacillariophyceæ; Schiller (1933–37) for the Dinophyceæ and Schiller (1930) for the Coccolithineæ; Gemeinhardt (1930) for the Silicoflagellatæ; Geitler (1932) for the Myxophyceæ (Cyanophyceæ); Gojdics (1953) and Subrahmanyan (1954 *a*) for the Euglenineæ; and Pascher (1913), Huber-Pestalozzi (1950) and Subrahmanyan (1954 *b*) for the Chloromonadineæ.

I should like to record here my thanks to Dr. N. K. Panikkar for his keen interest in the investigations.

LIST OF THE PHYTOPLANKTON ORGANISMS†

Bacillariophyceæ

1. *Melosira sulcata* (Ehrenb.) Kütz.
2. *Podosira montagnei* Kütz.
3. *Hyalodiscus subtilis* Bailey
4. *Pyxidicula minuta* Grunow
5. *Stephanopyxis turris* (Grev. *et* Arn.) Ralfs
6. *S. palmeriana* (Grev.) Grun.
7. *Sceletonema costatum* (Grev.) Cleve
8. *Porosira glacialis* (Grun.) Jörg.
9. *Coscinosira polychorda* Gran
10. *Thalassiosira decipiens* (Grun.) Jörg.
11. *T. hyalina* (Grun.) Gran
12. *T. baltica* (Grun.) Ostenf.
13. *T. kryophila* (Grun.) Jörg.
14. *T. coramandeliana* Subrahmanyan
15. *T. subtilis* (Ostenf.) Gran.
16. *T. nana* Lohmann
17. *Cyclotella meneghiniana* Kütz.
18. *C. striata* (Kütz.) Grun.
19. *Ethmodiscus gazellæ* (Janisch) Hustedt
20. *Coscinodiscus excentricus* Ehrenb.
21. *C. excentricus* var. *fasciculata* Hustedt
22. *C. lineatus* Ehrenb.
23. *C. sub-lineatus* Grun.
24. *C. stellaris* Roper
25. *C. rothii* var. *subsalsa* (Juhl.—Dannf.) Hustedt
26. *C. marginatus* Ehrenb.
27. *C. radiatus* Ehrenb.
28. *C. granii* Gough
29. *C. granii* var. *aralensis* (Ostenf. Hustedt
30. *C. jonesianus* (Grev.) Ostenf.
31. *C. jonesianus* var. *commutata* (Grun.) Hustedt
32. *C. concinnus* W. Smith
33. *C. schimperi* Karsten
34. *C. centralis* Ehrenb.
35. *C. perforatus* Ehrenb.
36. *C. perforatus* var. *pavillardi* (Forti) Hustedt
37. *C. apiculatus* Ehrenb.
38. *C. asteromphalus* Ehrenb.
39. *C. oculus-iridis* Ehrenb.
40. *C. oculus-iridis* var. *borealis* (Bailey) Cleve
41. *C. gigas* var. *prætexta* (Janisch) Hustedt

† The forms are arranged in their taxonomic order.

Bacillariophyceæ—(*Contd.*)

42. *C. janischii* A. Schmidt
43. *Planktoniella sol* (Wallich) Schütt
44. *Actinoptychus undulatus* (Bailey) Ralfs
45. *Asteromphalus robustus* Castracane
46. *A. flabellatus* (Bréb.) Grev.
47. *A. cleveanus* Grunow
48. *A. wyvillei* Castracane
49. *Aulacodiscus orbiculatus* Subrahmanyan
50. *Gossleriella tropica* Schütt
51. *Auliscus sculptus* (W. Smith) Ralfs
52. *Actinocyclus ehrenberghii* Ralfs
53. *A. tenuissimus* Cleve
54. *Bacterosira fragilis* Gran
55. *Corethron hystrix* Hensen
56. *C. inerme* Karsten
57. *Lauderia annulata* Cleve
58. *Schröderella delicatula* (Perag.) Pav.
59. *Leptocylindrus danicus* Cleve
60. *L. minimus* Gran
61. *L. adriaticus* Schröder ?
62. *Guinardia flaccida* (Castr.) Perag.
63. *G. blavyana* Perag.
64. *G. victoriæ* Karsten
65. *Rhizosolenia fragilissima* Bergon
66. *R. firma* Karsten
67. *R. cylindrus* Cleve
68. *R. stolterfothii* H. Perag.
69. *R. robusta* Norman
70. *R. imbricata* Brightwell
71. *R. imbricata* var. *shrubsolei* (Cleve) Schröder
72. *R. styliformis* Brightwell
73. *R. styliformis* var. *latissima* Brightwell
74. *R. styliformis* var. *longispina* Hustedt
75. *R. setigera* Brightwell
76. *R. hebetata* var. *semispina* (Hensen) Gran
77. *R. calcaravis* M. Schultze
78. *R. crassispina* Schröder
79. *R. alata* Brightwell
80. *R. alata* f. *gracillima* (Cleve) Grun.
81. *R. alata* f. *indica* (Perag.) Ostenf.
82. *R. alata* f. *inermis* (Castr.) Hustedt.
83. *R. acuminata* (Perag.) Gran
84. *R. castracanei* Perag.
85. *R. castracanei* var. *rhomboidea* Subrahmanyan
86. *Bacteriastrum minus* Karsten
87. *B. delicatulum* Cleve
88. *B. hyalinum* Lauder
89. *B. hyalinum* var. *princeps* (Castr.) Ikari
90. *B. varians* Lauder
91. *B. elongatum* Pav.
92. *B. mediterraneum* Pav.
93. *B. elegans* Pav.
94. *B. comosum* Pav.
95. *Chætoceros atlanticum* var. *neopolitana* (Schütt) Hustedt
96. *C. eibenii* Grun.
97. *C. coarctatus* Lauder
98. *C. tetrastichon* Cleve
99. *C. danicus* Cleve
100. *C. borealis* Bailey
101. *C. denticulatum* Lauder
102. *C. peruvianus* Brightwell
103. *C. peruvianus* var. *robusta* (Cleve) Hustedt
104. *C. decipiens* Cleve
105. *C. mitra* (Bailey) Cleve
106. *C. lorenzianus* Grun.
107. *C. indicus* Subrahmanyan
108. *C. lauderi* Ralfs
109. *C. compressus* Lauder
110. *C. didymus* Ehrenb.
111. *C. didymus* var. *protuberans* (Lauder) Gran *et* Yendo
112. *C. didymus* var. *heterosetoides* Subrahmanyan
113. *C. constrictus* Gran
114. *C. van Heurckii* Gran
115. *C. affinis* Lauder
116. *C. affinis* var. *intermedius* Subrahmanyan
117. *C. paradoxum* Cleve
118. *C. lascinosus* Schütt
119. *C. pelagicus* Cleve
120. *C. brevis* Schütt
121. *C. holsaticus* Schütt
122. *C. diversus* Cleve
123. *C. lævis* Leud.-Fort.
124. *C. ralfsii* Cleve
125. *C. messanensis* Castracane
126. *C. wighami* Brightwell
127. *C. fragilis* Meunier
128. *C. curvisetus* Cleve
129. *C. debilis* Cleve
130. *C. tortissimus* Gran
131. *C. socialis* Lauder
132. *C. simplex* Ostenf.
133. *C. myriapodus* Mangin
134. *Eucampia zodiacus* Ehrenb.
135. *E. cornuta* (Cleve) Grun.
136. *Climacodium frauenfeldianum* Grunow
137. *C. biconcavum* Cleve
138. *Streptotheca indica* Karsten
139. *Bellerochea mallevs* (Brightwell) van Heurck
140. *Ditylum brightwelli* (West) Grun.
141. *D. sol* Grun.
142. *Lithodesmium undulatum* Ehrenb.
143. *Triceratium favus* Ehrenb.
144. *T. robertsianum* Grev.

Bacillariophyceæ—(*Contd.*)

145. *T. dubium* Brightwell
146. *T. reticulatum* Ehrenb.
147. *T. alternans* Bailey
148. *Biddulphia pulchella* Gray
149. *B. sinensis* Grev.
150. *B. mobiliensis* Bailey
151. *B. heteroceros* Grun.
152. *B. japonica* Castracane
153. *B. rhombus* (Ehrenb.) W. Smith
154. *B. aurita* (Lyngb.) Bréb.
155. *B. longicruris* Greville
156. *Isthmia enervis* Ehrenb.
157. *Cerataulina bergoni* Perag.
158. *Hemiaulus hauckii* Grun.
159. *H. sinensis* Grev.
160. *H. membranaceus* Cleve
161. *Hemidiscus hardmannianus* (Grev.) Mann
162. *Rhabdonema mirificum* W. Smith
163. *Striatella delicatula* (Kütz.) Grun.
164. *Grammatophora undulata* Ehrenb.
165. *Licmophora abbreviata* Agardh
166. *L. debilis* (Kütz.) Grun.
167. *Climacosphenia moniligera* Ehrenb.
168. *C. elongata* Bailey
169. *Fragilaria oceanica* Cleve
170. *Raphoneis amphiceros* Ehrenb.
171. *R. discoides* Subrahmanyan
172. *Synedra formosa* Hantzsch
173. *Thallassionema nitzschioides* Grun.
174. *Thallassiothrix longissima* Cleve *et* Grun.
175. *T. frauenfeldii* Grun.
176. *T. antarctica* Schimper
177. *Asterionella japonica* Cleve
178. *Cocconeis sigmoides* Subrahmanyan
179. *C. littoralis* Subrahmanyan
180. *Achnanthes strömii* Hustedt
181. *Mastogloia exilis* Hustedt
182. *M. minuta* Grev.
183. *Gyrosigma balticum* (Ehrenb.) Rabenh.
184. *Pleurosigma capense* Karsten
185. *P. galapagense* Cleve
186. *P. elongatum* W. Smith
187. *P. normani* Ralfs
188. *P. angulatum* (Quekett) W. Smith
189. *P. angulatum* var. *strigosa* (W. Smith) van Heurck
190. *P. aestuarii* Bréb.
191. *P. carinatum* Donkin
192. *P. directum* var. *membranacea* Subrahmanyan
193. *Pleurosigma* sp.‡
194. *Caloneis madraspatensis* Subrahmanyan
195. *Diploneis weissflogii* (A. Sch.) Cleve
196. *D. puella* (Schumann) Cleve
197. *D. fusca* var. *subrectangularis* Cleve
198. *D. smithii* (Bréb.) Cleve
199. *D. robustus* Subrahmanyan
200. *Navicula longa* (Greg.) Ralfs
201. *N. hennedyii* W. Smith
202. *N. hennedyii* var. *nebulosa* (Greg.) Cleve
203. *N. clavata* Gregory
204. *N. forcipata* Greville
205. *N. membranacea* Cleve
206. *Pinnularia alpina* W. Smith
207. *Trachyneis aspera* var. *genuina* Cleve
208. *T. antillarum* Cleve
209. *Amphiprora gigantea* var. *sulcata* (O'Meara) Cleve
210. *Tropidoneis semistriata* Grun.
211. *Amphora lineolata* Ehrenb.
212. *A. decussata* Grun.
213. *A. ostrearia* Bréb.
214. *A. pusio* Cleve
215. *Cymbella marina* Castracane
216. *Bacillaria paradoxa* Gmelin
217. *Nitzschia pelagica* Karsten
218. *N. panduriformis* var. *continua* Grun.
219. *N. vitrea* Norman
220. *N. sigma* var. *indica* Karsten
221. *N. closterium* (Ehrenb.) W. Smith
222. *N. longissima* (Bréb.) Ralfs
223. *N. seriata* Cleve
224. *Surirella fluminensis* Grun.
225. *S. eximia* Grev.
226. *Campylodiscus iyengarii* Subrahmanyan

Dinophyceæ

227. *Haplodinium* sp.‡[1]
228. *Haplodinium* sp.‡[2]
229. *Desmocapsa* sp.‡
230. *Exuviælla compressa* Ostenfeld
231. *Prorocentron micans* Ehrenb.
232. *P. micans* var.‡
233. *P. sigmoides* Böhm.
234. *Phalacroma rotundatus* (Clap. *et* Lachm.) Kof. *et* Mich.
235. *P. dolychopterigium* Murray *et* Whitting
236. *Dinophysis ovum* Schütt

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‡The forms marked with ‡ appear to be new taxa and will be described with their Latin diagnoses in a later paper.

Dinophyceæ—(*Contd.*)

237. *D. acuminata* Clap. *et* Lachm.
238. *D. caudata* Saville-Kent.
239. *D. caudata* f. *acutiformis* Kof. *et* Skoggsberg
240. *D. miles* f. *indica* Ostenf. *et* Schmidt
241. *Amphisolenia elongata* Kof. *et* Skoggsberg
242. *A. bidentata* Schröder
243. *Ornithocercus magnificus* Stein s. str. Schütt
244. *Parahistoneis rotundata* Kof. *et* Mich.
245. *Oxyrrhis marina* Dujardin
246. *Amphidinium extensum* Wulff.
247. *Gymnodinium* sp.‡[1]
248. *G. gelbum* Kof.
249. *G. marinum* Saville-Kent.
250. *G. mirabile* f. ‡
251. *G. splendens* Lebour
252. *G. uberrimum* (Allman) Kof. *et* Swezy
253. *G. variabile* C. E. Herdman
254. *Gymnodinium* sp.‡[2]
255. *Gymnodinium* sp.‡[3]
256. *Massartia glauca* (Lebour) Schiller
257. *Gyrodinium aureum* Conrad
258. *G. citrinum* Kof.
259. *G. fusiforme* Kof. *et* Swezy
260. *G. lingulifera* Lebour
261. *G. obtusum* (Schütt) Kof. *et* Swezy
262. *G. pepo* (Schütt) Kof. *et* Swezy
263. *G. pingue* (Schütt) Kof. *et* Swezy
264. *G. spirale* (Bergh) Kof. *et* Swezy
265. *Polykrikos schwatrzii* Butschli
266. *Noctiluca miliaris* Suriray
267. *Paulsenella chætoceratis* (Paulsen) Chatton
268. *Sphærodinium* sp.‡[1]
269. *Sphærodinium* sp.‡[2]
270. *Pyrophacus horologicum* Stein
271. *P. horologium* var. *steinii* Schütt
272. *Glenodinium lenticula* f. *asymmetrica* (Mangin) Schiller
273. *G. pilula* (Ostenf.) Schiller
274. *G. trochoideum* Stein
275. *Peridinium bulla* Meunier
276. *P. hyalinium* Meunier
277. *P. minutum* Kof.
278. *P. thorianum* Paulsen
279. *P. excentricum* Paulsen
280. *P. globulus* Stein
281. *P. globulus* var. *quarnerense* Br. Schröder
282. *P. globulus* var. *ovatum* (Pouchet) Schiller
283. *P. granii* Ostenf.
284. *P. steinii* var. *mediterraneum* Kof.
285. *P. pedunculatum* Schütt.
286. *P. brochii* Kof. *et* Swezy
287. *P. brochii* var. *inflatum* (Okamura) Schiller
288. *P. crassipes* Kof.
289. *Peridinium* sp.‡
290. *P. divergens* Ehrenb.
291. *P. conicoides* Paulsen
292. *P. conicum* (Gran) Ostenf. *et* Schmidt
293. *P. conicum* f. *guardafuiana* Marz.
294. *P. humile* Schiller
295. *P. leonis* f. *matzenaueri* Schillet
296. *P. obtusum* Karsten
297. *P. pentagonum* Gran
298. *P. subinerme* Paulsen
299. *P. claudicans* Paulsen
300. *P. depressum* Bailey
301. *P. grande* Kof.
302. *P. murrayi* Kof.
303. *P. oceanicum* Vanhöffen
304. *P. venustrum* Matz.
305. *P. sinaicum* Matz.
306. *Gonyaulax diegænsis* Kof.
307. *G. scrippsæ* Kof.
308. *Ceratium candelabrum* f. *curvatulum* Jörg.
309. *C. candelabrum* f. *depressum* Pouchet
310. *C. furca* f. *eugrammum* (Ehrenb.) Jörg.
311. *C. teres* Kof.
312. *C. setaceum* Jörg.
313. *C. minutum* Jörg.
314. *C. inflatum* (Kof.) Jörg.
315. *C. longirostrum* Gourret
316. *C. fuscus* (Ehrenb.) Dujardin
317. *C. fuscus* var. *seta* (Ehrenb.) Jörg.
318. *C. dens* Ostenf. *et* Schiller
319. *C. tripos* var. *atlanticum* Ostenf.
320. *C. tripos* f. *ponticum* Jörg.
321. *C. tripos* f. *subsalsum* Ostenf.
322. *C. pulchellum* f. *semipulchellum* Jörg.
323. *C. humile* Jörg.
324. *C. breve* (Ostenf. *et* Schiller) Schröder
325. *C. bucephalum* (Cleve) Cl.
326. *C. karstenii* f. *robustum* (Karsten) Jörg.
327. *C. gibberum* Gourret
328. *C. lunula* Schimper
329. *C. schmidtii* Jörg.
330. *C. declinatum* Karsten
331. *C. longipes* (Bailey) Gran
332. *C. longipes* f. *balticum* Ostenf.
333. *C. horridum* Gran
334. *C. buceros* Zacharias s. dilet.
335. *C. vultur* var. *sumatranum* (Karst.) Stee -Nielsen

Dinophyceæ—(*Contd.*)

336. *C. massiliense* f. *macroceroides* (Karsten) Jörg.
337. *C. massiliense* f. *armatum* (Karsten) Jörg.
338. *C. carriense* f. *volans* (Cleve) Jörg.
339. *C. macroceros* (Ehrenb.) Cl.
340. *C. macroceros* var. *gallicum* (Kof.) Jörg.
341. *C. trichoceros* (Ehrenb.) Kof.
342. *Ceratocorys horrida* Stein
343. *Podolampas bipes* Stein
344. *P. palmipes* Stein
345. *Pyrocystis pseudonoctiluca* (Wy. Thompson) Schiller
346. *P.* (*Dissodinium*) *fusiformis* (Wy. Thomp.) Murray
347. *P.* (*Dissodinium*) *fusiformis f. biconica* Kof.

Chlorophyceæ

348. *Chlamydomonas* sp.‡
349. *Carteria* sp.‡

Chloromonadineæ

350. *Hornellia marina* Subrahmanyan

Myxophyceæ

351. *Lyngbya æstuarii* Liebm.
352. *Trichodesmium erythræum* Ehrenb.
353. *T. thiebautii* Gomont
354. *T. contortum* Wille
355. *Katagnymeme spiralis* Lemm.
356. *Anabæna* sp.‡
357. *Richelia intracellularis* Schmidt

Eugleninеæ

358. *Protæuglena noctilucæ* Subrahmanyan
359. *Euglena* sp.‡

Silicoflagellatæ

360. *Dictyocha staurodon* Ehrenb.
361. *D. fibula* var. *longispina* Lemm.
362. *D. fibula* f. *rhombica* Schulz
363. *D. fibula* var. *pentagona* Schulz
364. *Distephanus speculum* (Ehrenb.) Hæckel

Coccolithineæ

365. *Coccolithus pelagicus* (Wallich) Schiller
366. *Rhabdosphæra longistylis* Schiller

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A CONTRIBUTION TO THE LIFE-HISTORY OF *RUBIA CORDIFOLIA* LINN.

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INTRODUCTION

THE family Rubiaceæ has been of considerable interest to embryologists for a long time. The structure and morphology of the ovule in the family was studied by many investigators like Schleiden (1837), Warming (1878), Fagerlind (1937), Joshi (1938), Houk (1938), Mendes (1941) and a few others. Fagerlind (1937) has been able to trace a series of nucellar types in the family forming various steps of nucellar reduction culminating in the Houstonia type in which there is no distinguishable epidermis, the ovule consisting of only the sporogenous cells and the integument. Also, several interesting embryological features like the occurrence of multicellular archesporium, multiple embryo-sacs in the ovule, antipodal and suspensor haustoria have been reported in some members belonging to the tribe Galieæ. Three different types of embryo-sac development, namely, Polygonum type, Allium type and Drusa type occur in the members of the family (Karsten, 1891; Fagerlind, 1937). Solanad type of embryo development has been described in representatives of five of the nineteen tribes recognised in the family (Souèges, 1924; Johansen, 1950). Ruminate endosperm has been found in *Psychotria emetica* (Fagerlind, 1937). Suspensor haustorium formation is found in *Phyllis* and in some members of Galieæ.

The previous work in the family up to 1930 has been summarised by Schnarf (1931). Subsequent to the publication of Schnarf's book the most important contribution is that by Fagerlind (1937) who made a comprehensive and exhaustive study of a large number of genera, in this family. Houk (1938), Joshi (1938) and Mendes (1941) have studied the ovule and seed structure in *Coffea* and *Cinchona*. Raghavan and Rangaswamy (1941) studied *Dentella repens* and *Oldenlandia alata* while Raghavan and Srinivasan (1941) studied *Spermacoce hispida* and *Guettarda speciosa*. Farooq (1952) reinvestigated *Borreria hispida* (*Spermacoce hispida*) and found some observations made earlier by Raghavan and Srinivasan (1941) to be erroneous. Farooq (1953) also investigated *Oldenlandia corymbosa* and reported, for the first time, the occurrence of non-nucleate endosperm vesicles in the family. The present authors published a preliminary report of the embryology of *Rubia cordifolia* and *Hamelia patens* (Venkateswarlu and Rajeswara Rao, 1954) in 1954. Since then Ramam (1954) has described the gametophytes in *Stephegyne parviflora* and Ganapathy (1956 *a* and 1956 *b*)

studied the embryology of *Hydrophylax maritima* L.f. and *Ophiorrhiza mungos* L. in the latter of which he reported the formation of cellulai endosperm.

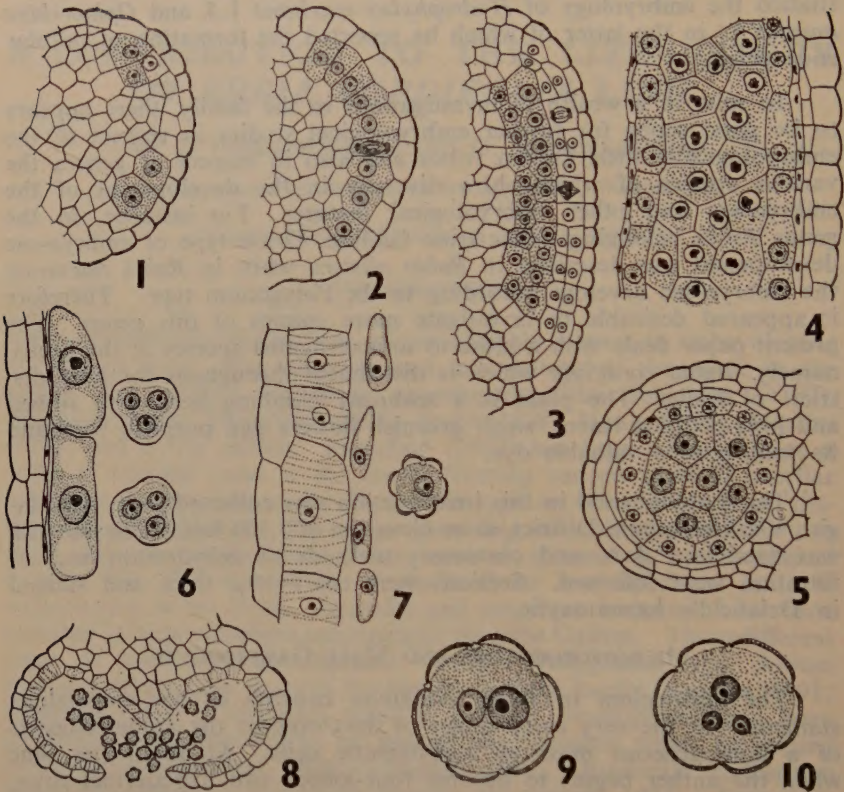
In spite of a wealth of investigations in the family, there appears to be good scope for further embryological studies in respect of the embryologically little known tribes and also in respect of genera the various species of which show diversity in the development of the embryo-sac and other embryological features. For instance, in the genus *Rubia* belonging to the tribe Gallieæ, Drusa type of embryo-sac development was described in *Rubia olivierii* while in *Rubia tinctorum* the embryo-sac develops according to the Polygonum type. Therefore it appeared desirable to investigate more species of this genus. The present paper deals with a hitherto uninvestigated species of the genus, namely, *Rubia cordifolia* which is distributed throughout the hilly districts of India. The plant is a scabrous climbing herb with ribbed and long-petioled leaves, small greenish flowers and purplish fruit and its roots give a valuable dye.

The material used in this investigation was collected from Anantagiri, Visakhapatnam District, at an elevation of 3,500 feet. The material was fixed in F.A.A. and customary methods of dehydration and infiltration were followed. Sections were cut 6–10 μ thick and stained in Delafield's hæmatoxylin.

Microsporogenesis and Male Gametophyte

The andrœcium in *Rubia cordifolia* consists of five epipetalous stamens. In the very early stages of development the anther consists of a homogeneous mass of meristematic cells. At about the time when the anther begins to become four-lobed, two hypodermal rows, each of 8–10 cells with dense cytoplasm and prominent nuclei, become distinguishable in each of the four lobes (Text-Figs. 1 and 2). The archesporial cells divide periclinally forming a layer of primary parietal cells to the outside and a layer of primary sporogenous cells to the inside. Further periclinal divisions in the parietal cells result in the formation of three wall layers below the epidermis in the anther (Text-Figs. 3–5) of which the innermost forms the tapetum. Later the outermost of these layers forms the fibrous endothecial layer (Text-Fig. 7), and the middle layer becomes crushed (Text-Figs. 5–6). In the meanwhile the primary sporogenous cells undergo mitotic divisions in all directions and form the microsporogenous tissue occupying the portion of the anther inner to the tapetum (Text-Figs. 3–5).

The anther tapetum consists of a single layer of uninucleate cells which are rich in cytoplasm and stain deeply (Text-Figs. 4–7). The tapetal cells in this plant unlike in many angiosperms remain uninucleate throughout. The anther tapetum is of the secretory type. A close series of stages of anther during its development have been examined to see whether the tapetal cell nuclei divide and become 2-nucleate and further acetocarmine smears of the tapetal cells have also been studied on this point. However, no 2-nucleate tapetal cells have been



TEXT-FIGS. 1–10. Microsporogenesis. Fig. 1. T.S. anther lobe showing primary archesporium (one of the archesporial cells has cut off a parietal cell), ×433. Fig. 2. L.S. anther lobe showing a row of hypodermal archesporial cells, ×433. Fig. 3. L.S. anther lobe showing epidermis, the primary parietal layer which has divided once periclinally at some places and the primary sporogenous layer which has already divided periclinally once, ×433. Fig. 4. L.S. anther lobe showing epidermis, two wall layers and tapetum surrounding the sporogenous tissue. The P.M.C. nuclei are in I meiotic metaphase, ×433. Fig. 5. T.S. of an anther lobe showing the wall layers and tapetum surrounding the sporogenous tissue, ×433. Fig. 6. L.S. Part of an anther lobe showing structure of the wall, tapetum and 4-nucleate P.M.C. in cytokinesis, ×733. Fig. 7. Later stage than that in Fig. 6 showing 1-nucleate pollen grains. The middle layers of the wall have disappeared and endothecium is differentiated, ×733. Fig. 8. T.S. half of a mature anther showing epidermis and endothecium, ×188. Figs. 9 and 10. Sections of 2-nucleate and 3-nucleate pollen grains respectively, ×1,250.

encountered. The tapetal cells in *Rubia cordifolia* remain at the periphery of the sporogenous tissue and they become absorbed by the time mature pollen grains are formed. The division of P.M. Cells is simultaneous. Cytokinesis is by furrowing. Both bilateral and tetrahedral types of tetrads are formed, the latter being more common. The pollen grains become free from the tetrad condition when they are at the uninucleate stage and the differentiation of exine takes place

soon after (Text-Fig. 7). The 2-nucleate pollen grain contains a large vegetative and a small generative nucleus (Text-Fig. 9). The pollen at the shedding stage is three-celled (Text-Fig. 10). Usually the exine shows six ridges but pollen grains with five or seven ridges in the exine are also occasionally met with. There are as many germ pores as there are ridges. In section the exine shows rod-like regions which on the surface form a feeble polygonal pattern. In the mature anther the adjacent locules in each anther lobe fuse together (Text-Fig. 8).

Megasporogenesis and Female Gametophyte

The ovary is inferior, bicarpellary and bilocular with a single ovule in each loculus. The placentation is axile. The ovule primordium arises as a hemispherical protuberance on the placenta and as it grows it bends towards the base of the ovary, eventually becoming anatropous in its mature condition. The micropyle is long (Text-Figs. 12 and 14), very narrow and directed towards the base of the ovary. The integument is massive and is about 10–14 cells thick in an ovule containing the megaspore tetrad. There is not much increase in the thickness of the integument in older stages of the ovule.

The nucellus is rudimentary and consists of only a few nucellar epidermal cells which lie at the micropylar end overlying the female archesporium (Text-Fig. 11). In mature ovules even the few nucellar cells constituting the nucellar epidermis are completely crushed and obliterated. Fagerlind (1937), on the basis of an extensive study of the ovule in the family, recognised six types, namely, Phyllis type, Bouvardia type, Oldenlandia type, Vaillantia type, *Rubia olivierii* type and Houstonia type. That found in *Rubia cordifolia* belongs to the Vaillantia type. It may be pointed out here that in *Rubia olivierii* the number of epidermal cells constituting the nucellus is only four and the cells are very elongated radially whereas in *Rubia cordifolia* the number of cells is larger and the cells are also not radially elongated thus resembling the Vaillantia type more closely than *Rubia olivierii* type.

The primary archesporium in the ovule is multicellular, its outermost cells lying immediately below the cells forming the nucellar epidermis while the rest lie below them (Text-Fig. 11). The archesporial cells seem to be embedded in the integument tissue and may be recognised from the cells of the latter by their large size, conspicuous nuclei and deep staining capacity. No parietal cells are cut off by them. The archesporial cells enlarge in size and become directly the megaspore mother cells. The meiotic divisions in the various megaspore mother cells in the ovules are not synchronous. For instance, Text-Fig. 13 shows eight megaspore mother cells of which the nuclei in three show first meiotic metaphase and in five show prophase. In most megaspore mother cells contained in an ovule the second meiotic division also takes place and upto 4–5 linear megaspore tetrads are formed in an ovule. For instance, the ovule sketched in Text-Fig. 15 contains two linear tetrads in addition to four megaspore mother cells with their

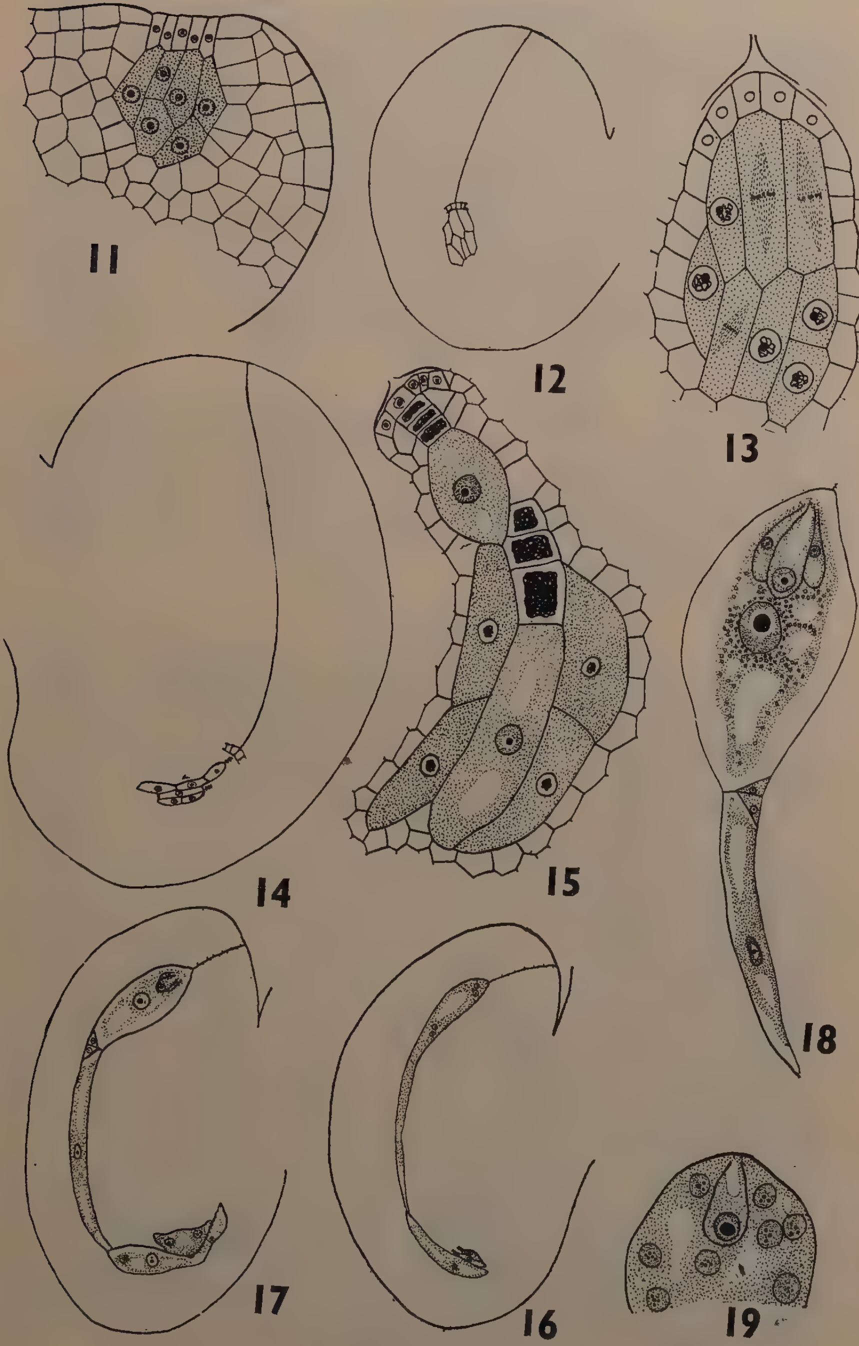
nuclei in first meiotic prophase and Text-Fig. 16 shows a 4-nucleate embryosac, one uninucleate embryo-sac and two linear tetrads of megaspores in each of which the chalazal megaspore has enlarged. Usually the chalazal megaspore of the tetrad is functional while the three micropylar ones degenerate. Some of the megaspore mother cells degenerate without undergoing meiosis fully or even partly. Usually the functional megaspore of the tetrad lying nearest the micropyle is more successful while the others remain at earlier stages of development and are situated towards the chalazal end of the ovule (Text-Fig. 17). Usually one or two 8-nucleate embryo-sacs are formed in each ovule owing to the further development of the functional megaspores of separate tetrads as a consequence of three successive free nuclear divisions in them. Besides these 8-nucleate embryo-sacs one or two megaspore tetrads may also be found in the chalazal part of some ovules. Usually, however, only one 8-nucleate embryo-sac seems to enlarge further while the rest do not attain their full size.

The mature embryo-sac shows an egg apparatus consisting of a flask-shaped egg with a nucleus at its basal end and a prominent vacuole above it and two pear-shaped synergids with a vacuole at the basal end and a large prominent nucleus above it (Text-Fig. 18). The synergids are without hooks. The polar nuclei fuse together to form the secondary embryo-sac nucleus which takes its position near the egg apparatus. Three uninucleate antipodal cells are formed. One peculiarity is that the basal of the three antipodal cells elongates very considerably and forms a tube-like structure (Text-Fig. 18). It extends to the chalazal part of the ovule and there it is surrounded by the undeveloped megaspore mother cells and ill-developed embryo-sacs. Obviously the latter afford nourishment which is absorbed by this aggressive antipodal cell functioning as a haustorium. The nucleus of this aggressive antipodal enlarges in size in comparison with nuclei of the rest of the two antipodals (Text-Fig. 18). The latter remain as small cells and lie to one side at the junction between the enlarged antipodal cell and the rest of the embryo-sac. Such a behaviour of the antipodals has been previously described in other members of Galieæ like *Callipeltis cucullaria* (Lloyd, 1902), *Rubia tinctorum*, *Galium aparine*, *Galium mollugo* (Fagerlind, 1937), and also in *Putoria calabrica* (Fagerlind, 1936), a member of Psychotrieæ. The embryo-sac development in *Rubia cordifolia* conforms to the Polygonum type (Maheshwari, 1950) and resembles that described in *Rubia tinctorum* by Fagerlind (1937). It may be mentioned that in *Rubia olivierii* investigated by the same author, Drusa type of embryo-sac development is found to take place.

Starch grains occur in abundance in the cytoplasm of the embryo-sac.

ENDOSPERM

The endosperm development is of the free nuclear type. The division of the primary endosperm nucleus takes place much earlier than that of the fertilised egg (Text-Fig. 19). The endosperm nuclei increase in number by further divisions and are distributed in the



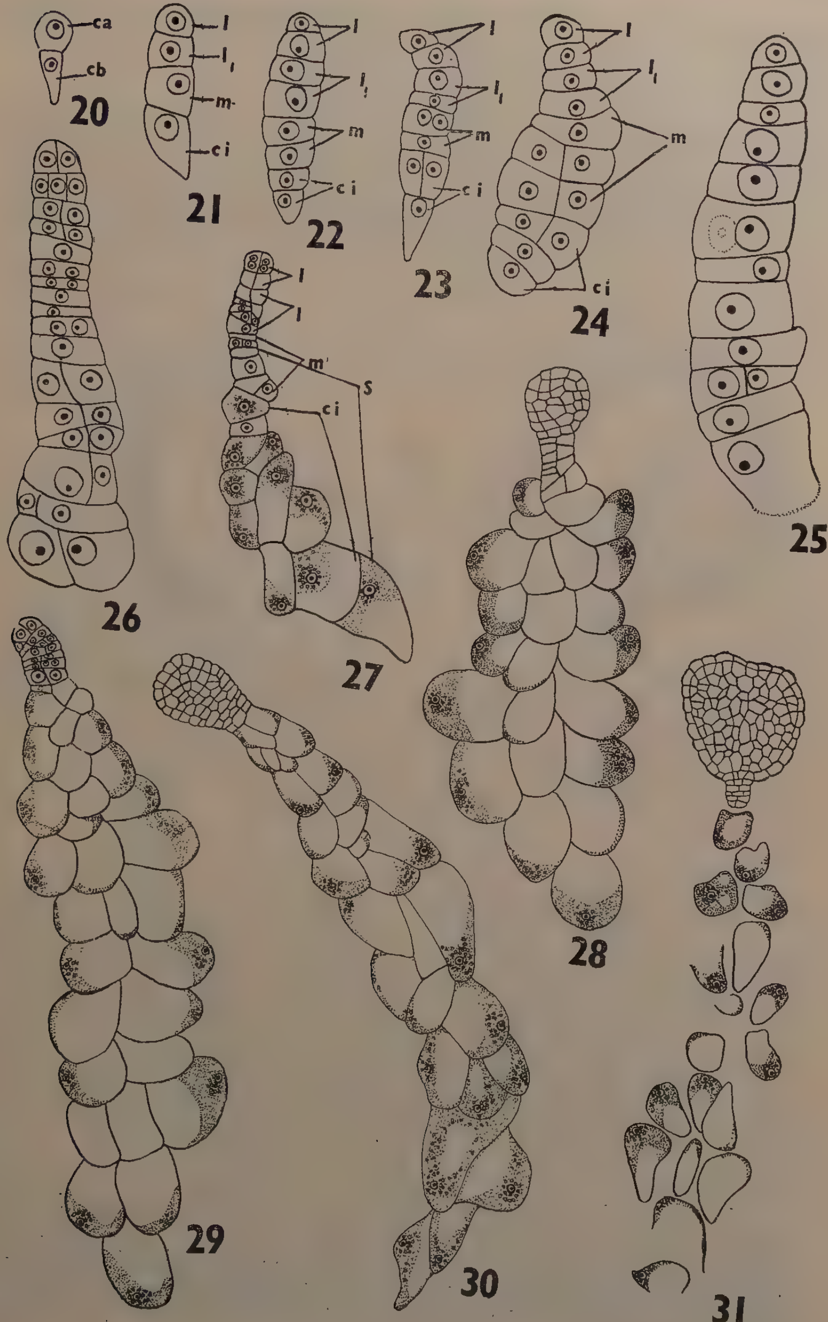
TEXT-FIGS. 11–19.

TEXT-FIGS. 11–19. Megasporogenesis. Fig. 11. L.S. ovule showing five nucellar cells, multicellular archesporium and the integumental tissue, ×540. Fig. 12. L.S. ovule showing many megaspore mother cells, ×203. Fig. 13. Part of the above enlarged. The megaspore mother cell nuclei are in I meiotic prophase and some in metaphase, ×792. Fig. 14. L.S. ovule showing long micropyle, massive integument, nucellus constituted by a few nucellar epidermal cells, megaspore tetrads and some m.m. cells, ×203. Fig. 15. Part of Fig. 14 enlarged to show details relating to megaspore tetrads and megaspore mother cells in the ovule, ×792. Fig. 16. L.S. ovule showing a 4-nucleate embryo-sac towards the micropylar end and younger embryo-sacs and megaspore tetrads at the chalazal end of the ovule, ×1,350. Fig. 17. L.S. ovule showing a mature embryo-sac with the antipodal haustorium and a fully developed but smaller-sized embryo-sac and a 2-nucleate embryo-sac in the chalazal, part of the ovule, ×135. Fig. 18. A mature embryo-sac showing egg apparatus, secondary nucleus, two small antipodals and the basal elongated antipodal haustorium. Starch grains are present in the embryo-sac, ×396. Fig. 19. Upper part of the embryo-sac showing a few endosperm nuclei and the fertilised egg still lying undivided, ×873.

peripheral lining of cytoplasm in the embryo-sac which encloses a central vacuole. By the time a 4-celled pro-embryo is formed the endosperm becomes cellular. In ovules in which the embryo becomes globular and a suspensor haustorium is developed, the endosperm cells adjoining the embryo become free from one another presumably owing to the invasion of the swollen vesicular cells of the aggressive suspensor haustorium.

EMBRYO

The first division of the fertilised egg is transverse and takes place only after a few divisions in endosperm are completed and some endosperm nuclei are already formed. The 2-celled pro-embryo consists of the terminal cell *ca* and the basal cell *cb*, which divide transversely forming a row of four cells which may be designated *l*, *l'*, *m* and *ci* (Text-Fig. 21). Each of these once again divides transversely giving rise to an 8-celled proembryo comprising 8 tiers of cells (Text-Fig.22). In *Sherardia arvensis* (Souèges, 1924) with which *Rubia cordifolia* agrees in essentials, however, sometimes the 8-celled stage is found to comprise 7 or 6 tiers owing to occurrence of vertical divisions in both *l* and *l'* or in either of them at the 4-celled stage of the embryo Such a variation has not been met with by us in *Rubia cordifolia.* Further divisions take place first, mostly in the lower four tiers (Text-Figs. 23, 24 and 25), the derivatives of which give rise to a prominent suspensor. The tiers derived from *m* and *ci*, divide vertically earlier than those derived from *l* and *l'* also divide vertically (Text-Figs. 26 and 27). The derivatives of *l* give rise to the cotyledons and the stem apex and the derivatives of *l'* give rise to the hypocotyl and root tip. Before forming the respective regions mentioned above, the tiers *l* and *l'* each form 3 or 4 tiers through transverse divisions of their derivatives. The cell *m* divides transversely and forms a number of flattened cells, the one nearest the embryonal mass contributing to complete the root cap (Text-Figs. 28 and 30). The rest of the derivatives of *m* add to the slender portion of the suspensor which is proximal to the embryo proper while the bulk of the suspensor is formed by the derivatives of *ci* (Text-Figs. 28, 29 and 31). The latter form a conspicuous part of



TEXT-FIGS. 20–31.

TEXT-FIGS. 20–31. Various stages in the development of the embryo. *ca*, Terminal cell; *cb*, Basal cell; *l*, and l_1, daughter cells arising out of first trasverse division in *ca*; *m*, and *ci*, daughter cells arising out of the first division in *cb*; *s*, suspensor. Figs. 20–26, ×435; Figs. 27, ×187; Figs. 28–31, ×165.

the suspensor comprising a number of vesicular cells with prominent vacuoles. The cytoplasm in these cells is mostly confined to the periphery and abundant starch grains are present in them (Text-Figs. 28 and 31), and forms an effective intra-endospermal haustorium (Text-Fig. 32). Suspensor haustoria have been described previously in other

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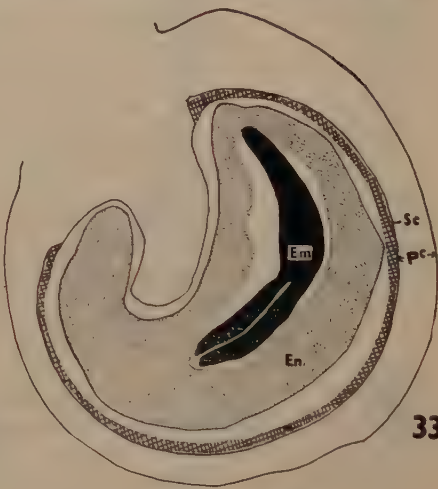

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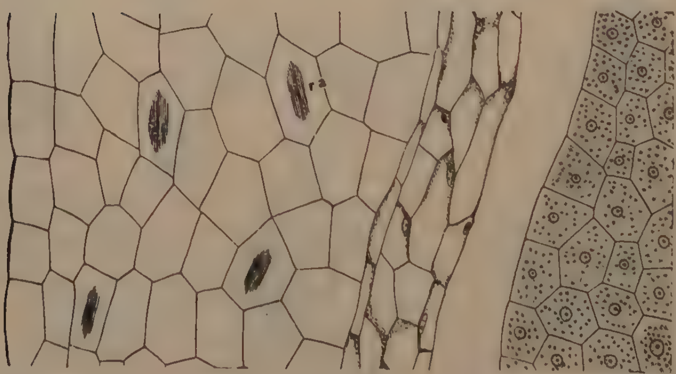

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TEXT-FIGS. 32–34. Structure of the mature seed. *Em*, embryo; *End*, endosperm; *Sc*, seed-coat (integument); *Pc*, Pericarp; *ra*, raphides. Fig. 32. L.S. seed containing an embryo showing the suspensor haustorium and the cotyledonary protuberances, ×27. Fig. 33. L.S. mature seed with fully differentiated embryo. The seed-coat is represented by a few layers of the integument, ×21. Fig. 34. A part of Fig. 33 enlarged to show detailed structure of the endosperm, seed-coat and the pericarp, ×219.

members of Galieæ like *Vaillantia hispida, Asperula azurea* (Lloyd, 1902) and *Galium articulatum* (Fagerlind, 1937).

From the above details it can be seen that derivatives of the basal cell *cb* of the two-celled pro-embryo do not take any part in the formation of the embryo proper and that the 4-celled pro-embryo consists of a linear row of 4 cells. These features characterise the Solanad type of embryo development. Further a hypophysis initial is not clearly distinguishable and the primordium of the root cap is formed from the derivatives of the uppermost cell arising out of transverse divisions of the cell *m*. The proximal part of the suspensor is filamentous while the distal part is thick consisting of a number of bladder-like haustorial cells. The proximal filamentous region is formed by the derivatives of *m* while the distal thick region is contributed to by derivatives of *ci*. These features are characteristic of the Sherardia Variation of the Solanad type.

SEED

The seed is albuminous (Gamble, 1935) and the structure is shown in Text-Figs. 32–34. During the development of the seed the integument is crushed and disorganised except for a few layers (Text-Fig. 34) which are closely appressed to the innerside of the pericarp which consists of about 10 layers of cells some of which contain raphides. The endosperm becomes cellular and forms two zones, a peripheral one consisting of smaller thick-walled cells and an inner zone of thin-walled larger cells (Text-Fig. 32). During advanced stages of embryo development, the inner region is mostly absorbed and a cavity is formed containing the nutritive substances produced by the disorganisation of the central mass of the endosperm tissue. In ripe seeds, it is probable, that the integument may further become absorbed, only forming a very thin covering.

DISCUSSION

The tapetal cells in *Rubia cordifolia* are uninucleate. Recently Ramam (1954) in *Stephegyne parviflora* and Ganapathy (1956 *a*) in *Hydrophylax maritima* also reported this feature in them. No specific statement on the number of nuclei in the tapetal cells is found in many of the published papers dealing with various Rubiaceæ but in *Dentella repens* and *Oldenlandia alata* Raghavan and Rangaswamy (1941) reported that they become binucleate. A close study of the tapetal cells in this family seems to be necessary before determining whether the tapetal cells remain uninucleate in members of Rubiaceæ as a rule or not. Uninucleate tapetal cells are known to occur in members of various other families such as Mimosaceæ, Crassulaceæ, Gentianaceæ, Boraginaceæ, Hydrophyllaceæ, Juncaceæ, Orchidaceæ and Helobiales (*see* Maheshwari, 1950).

Fibrous endothecium in the anther is found in *Rubia cordifolia* (present study) as also in *Stephegyne parviflora* (Ramam, 1954). However, Ganapathy (1956 *a*) reported the absence of fibrous thickenings in the endothecium in *Hydrophylax maritima* and a similar condition

has been figured by Raghavan and Srinivasan (1941) in *Spermacoce hispida*.

In *Hydrophylax maritima* Ganapathy (1956 *a*) observed that in the development of the anther there is no fusion of the adjacent locules even at the time of shedding of pollen grains. But in *Rubia cordifolia* (present study) the adjacent locules fuse in each anther lobe.

The morphology of the ovule in the family has specially attracted the attention of several investigators and only recently it is clearly understood. Schleiden (1837) characterised the ovules in Rubiaceæ as naked. Warming (1878) and Lloyd (1902) have considered the tissue of the ovular body as undifferentiated integument *cum* nucellus and to them we owe the 'integument-nucellus' concept. Von Faber (1912), Dahlgren (1927), Schnarf (1931), Fagerlind (1937), Joshi (1938), Mendes (1941), Raghavan and Rangaswamy (1941), and Raghavan and Srinivasan (1941) are of the opinion that the rubiaceous ovule consists of a massive integument and a nucellus consisting of a variable number of nucellar epidermal cells ranging from one to few either confined to the region immediately above the archesporium or also extending to the sides of the same. In *Houstonia*, however, the nucellar epidermal cells are completely suppressed. Fagerlind (1937) investigated many genera in the family and recognised a number of nucellar types in the family representing a reduction series in respect of the number of the nucellar epidermal cells. The ovule of *Rubia cordifolia* belongs to Vaillantia type. This differs from that found in *Rubia olivierii* and in Fagerlind's scheme it is derived as an offshoot from Bouvardia type, where nucellar epidermal cells are few and lie immediately above the archesporium and the reduction in the number of cells is accompanied by a pronounced radial elongation of the cells, the latter blocking the narrow micropylar canal and making the ovule look like a mass of tissue with no micropyle. Raghavan and Srinivasan (1941) have suggested two alternative schemes of reduction which represent slight modifications from the scheme given by Fagerlind (1937), but *Rubia olivierii* type, however, has not been included in their series. Since one of the two species of *Rubia*, namely, *Rubia cordifolia* belongs to the Vaillantia type, the derivation of *Rubia olivierii* type in Fagerlind's scheme from Bouvardia type through Vaillantia type is justified. Thus the nucellar type found in the two species of the genus *Rubia*, namely, *R. cordifolia* and *R. olivierii* is different.

Rubia cordifolia resembles in a striking manner the other members of Galieæ in the formation of a multicellular archesporium, multiple embryo-sacs, formation of antipodal and suspensor haustoria and Solanad type of embryo development. It may be pointed out that in the three species of *Rubia* investigated, including *Rubia cordifolia*, the embryo-sac development is not of the same type.

For instance in *Rubia olivierii*, Drusa type has been described by Fagerlind (1937). Thus *Rubia cordifolia* not only differs from *R. olivierii* in respect of the number of nucellar epidermal cells but also in the type of embryo-sac development. In *R. tinctorum* investigated by

Fagerlind, embryo-sac development is of the Polygonum type as in *R. cordifolia* (present study). Another feature of similarity between *R. tinctorum* and *R. cordifolia* is the behaviour of the basal antipodal cell which enlarges and becomes an elongated structure forming a haustorium. In the formation of multicellular archesporium and multiple embryo-sacs it resembles other members of Galieæ.

Endosperm is of the free nuclear type. It becomes cellular ultimately and the cells of the outer layer become thick-walled and persist in the seed. Cellular type of endosperm development has been recently reported in *Ophiorrhiza mungos*, a member of Rubiaceæ (Ganapati, 1956 *b*). The integument becomes absorbed mostly and remains only as a thin coat. In this respect it resembles most other Rubiaceæ. Embryo development keys out to the Sherardia Variation of the Solanad type and a very well developed suspensor haustorium is found as in other investigated members of Galieæ.

Summary

The primary archesporium in the anther is hypodermal in origin. The anther wall consists of epidermis, endothecium, single middle layer which is crushed later on and tapetum. The tapetum is of secretory type. The tapetal cells remain uninucleate throughout the development of the anther. The division of the pollen mother cells is of the simultaneous type. Both bilateral and tetrahedral types of pollen tetrads are formed, the later being more common. Cytokinesis is by furrowing. Usually the exine shows six ridges.

Ovules of *Rubia cordifolia* are unitegmic, tenuinucellate and anatropous. Nucellus is represented by only a few cells which lie immediately above the multicellular archesporium and is of Vaillantia type. In later stages the nucellus is completely destroyed. Most of the cells in the multicellular archesporium undergo meiotic divisions and form linear tetrads of megaspores. Chalazal megaspores of the tetrads are functional. A few embryo-sacs are produced in the ovule and usually one of them develops fully. The embryo-sac develops according to the Polygonum type. The mature embryo-sac shows an egg apparatus consisting of three cells, an egg and two synergids without hooks, secondary embryo-sac nucleus and three antipodals. The basal antipodal cell elongates considerably and forms a tube-like structure functioning as a haustorium. At this stage of the ovule, the antipodal haustorium is found to be surrounded by undeveloped megaspore mother cells and ill-developed embryo-sacs. Starch grains are found in the mature embryo-sac.

Endosperm is of free nuclear type.

The embryo develops according to the Solanad type and keys out to the Sherardia Variation. A very well developed suspensor haustorium is found. In the mature seed the cells of the outer layer of endosperm become thick-walled and it persists in the seed, while the integument becomes absorbed mostly and remains only as a thin coat.

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THE CLAVARIACEÆ OF THE MUSSOORIE HILLS—X

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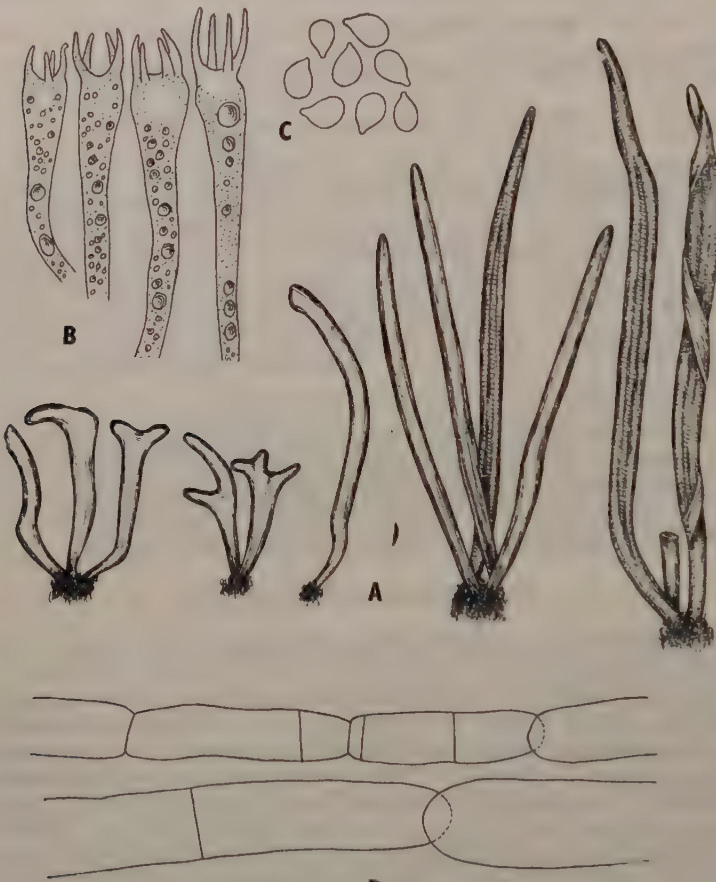
This paper is intended to record more Clavarias from the Mussoorie Hills in the North-Western Himalayas as a part of the study of the Fungal Flora of that region undertaken by Dr. K. S. Thind and his students. The first nine contributions (listed under references) describe 38 known Clavarias (mostly new records for India), 11 new species and 9 new varieties. This tenth contribution deals with 8 more known species all of which are new records for India. It also describes a 'haploid state' of *Clavulinopsis corniculata* (Fr.) Corner, which is reported here for the first time.

The classification of Corner (1950) has been followed in this series. The numbers of the species are the serial numbers of the Clavaroid flora of the Mussoorie Hills. Type collections have been deposited in the Herbarium of the Panjab University. Duplicate material is at the Botany School, University of Cambridge, England.

59. *Clavaria vermicularis* Fr.

Fructifications up to 13 cm. tall, gregarious, mostly cæspitose with 2–7 clubs, individual clubs up to 5 mm. wide, sometimes solitary, erect, medium-sized, radial or cylindric, trunk present, simple, sometimes forked once, rarely forked twice, fleshy, very brittle, smooth, glabrous, white, becoming pale yellow and flattened when old, turning ochraceous on drying; head 2–12 cm. × 1–5 mm., white, cylindric, often becoming flattened and longitudinally grooved along the middle when mature, sometimes twisted and flexuous, tapering upward, hollow, apex concolorous, acute in young and obtuse in mature clubs, sometimes flattened; trunk 0·5–2 cm. × 1–3 mm., white, concolorous, small, indistinct, cylindric, sterile, hollow, sometimes solid, hyphæ of the stem often loosened out so as to give a hairy appearance as observed under low power of the microscope; flesh concolorous, unchanging; taste and smell inparticular. *Hymenium* spread all over except the sterile trunk, not thickening, up to 50 μ broad; subhymenium hyphæ slender, very fine, interwoven, not inflating, 1–4 μ wide. *Basidia* 36–44 × 4–6·4 μ, clavato-elongate, without clamps, multiguttulate; sterigmata 4, long, straight to slightly incurved, 4–8 μ long. *Basidiospores* 4–5·6 × 3–4 μ, hyaline, broadly ellipsoid to subglobose to globose, papillate, papilla conspicuous, up to 1 μ long, smooth, aguttate. *Hyphæ* monomitic, 2–16 μ wide, sometimes up to 32 μ wide, hyphal cells mostly short, longitudinal, closely packed so as to give a pseudoparenchymatous

appearance, mostly 30–90 μ long, but reaching a maximum length of 240 μ in several cases and up to 340 μ in rare cases, inflated, thin-walled, hyaline, rarely branched, septate, without clamps, frequently secondarily septate, more or less constricted at the primary septa. (Text-Fig. 1, A-D.)



TEXT-FIG. 1. *Clavaria vermicularis* Fr. A. Fructifications, ×1. B. Multi-guttulate basidia, ×1,150. C. Basidiospores, ×1,150. D. Secondarily septate hyphæ, ×500.

Collected on soil under Oak forest, The Park, Mussoorie, September 7, 1956, 277; on bare earth under Oak forest, The Park, Mussoorie, September 7, 1956, 278; on soil under Oak forest, Brewery Road, Mussoorie, August 11, 1956, 279.

These Mussoorie collections characterized by the white, very brittle, simple, often cæspitose clubs, usually with indistinct and small stems undoubtedly belong to *Clavaria vermicularis* Fr. The species is

very common in the Mussoorie hills and shows luxuriant growth under the Oak forest on humicolous soil. Those growing on bare earth and somewhat exposed places remain stunted in their growth. The clubs usually turn yellowish with age.

60. *Clavaria zollingeri* Lév.

Fructifications up to 9·3 cm. tall and up to 5·7 cm. broad, solitary, erect, medium-sized, radial, trunk present, copiously branched, fleshy, brittle, smooth, glabrous, light to pale violet, on drying turning brown; trunk lighter coloured, 1·5 cm.×8 mm., slightly flattened, sterile, small; branching dichotomous, up to 5 times divided, regular, equal to unequal, in alternating planes, branches lax, axils rounded; primary branches up to 6 mm. wide, slightly flattened; ultimate branchlets very short to long, up to 1·8 cm. long, radial; apices blunt, fertile, concolorous; flesh lighter coloured, unchanging; smell and taste inparticular. *Hymenium* spread all over except the sterile trunk, not thickening, up to 70 μ thick; subhymenium up to 20 μ thick, cells narrow, 2–4 μ wide, gradually inflating up to 12 μ wide. *Basidia* 36–60×5·6–6·4 μ, clavato-elongate, multiguttulate; sterigmata 4, straight to slightly incurved, 4·8–7·2 μ long. *Basidiospores* 4·8–5·6 ×3·6–4·4 μ, hyaline, globose to subglobose, papillate, papilla small, up to 0·8 μ long, smooth, aguttate. *Hyphæ* monomitic, 3–18 μ wide, hyphal cells up to 90 μ long, brown in a mass, hyaline individually, slightly thick-walled, branched, branches sparse to rare, septate, septa at short intervals, not clamped, frequently secondarily septate, more or less constricted at the primary septa. (Text-Fig. 2, A-B.)

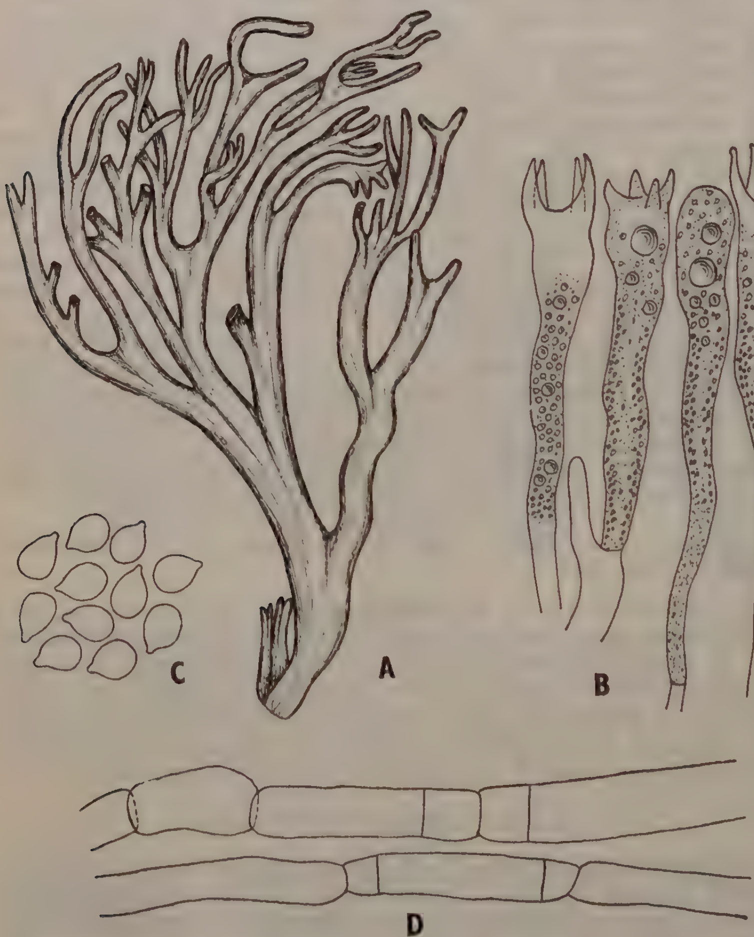
Collected on soil under Oak forest, Brewery Road, Mussoorie, August 11, 1956, 280.

This Mussoorie fungus undoubtedly belongs to *Clavaria zollingeri* Lév. However, only one fruit body has been observed and collected so far in India, probably indicating its rare occurrence. According to Corner (1950), *C. zollingeri* is a cosmopolitan species of great variability. It is the only branched species of *Clavaria* s. str., other than *C. fossicola* Corner (Corner, 1950), yet it varies into the almost simple, cæspitose state of *C. xylarioides* Petch (Corner, 1950).

61. *Clavulina subrugosa* (Clel.) Corner

Fructifications up to 5·8 cm. tall, densely gregarious, usually, singly, sometimes in small cæspitose clusters with 2–4 clubs, individual clubs up to 9 mm. wide, erect, medium-sized, cylindric to flattened, sometimes spathulate, often connate, the free upper portions of connate clubs often appearing as a fork, trunk present, mostly simple, sometimes branched once to several times, branches small to long, usually in one plane and appearing palmate, irregular and often adventitious type, fleshy, smooth, glabrous, creamy white to dull white, turning brown on drying; head 1·3–4·8 cm.×1·5–9 mm., creamy white, cylindric, becoming flattened and longitudinally grooved, twisted and flexuous when mature, often connate below and free above, sometimes becoming

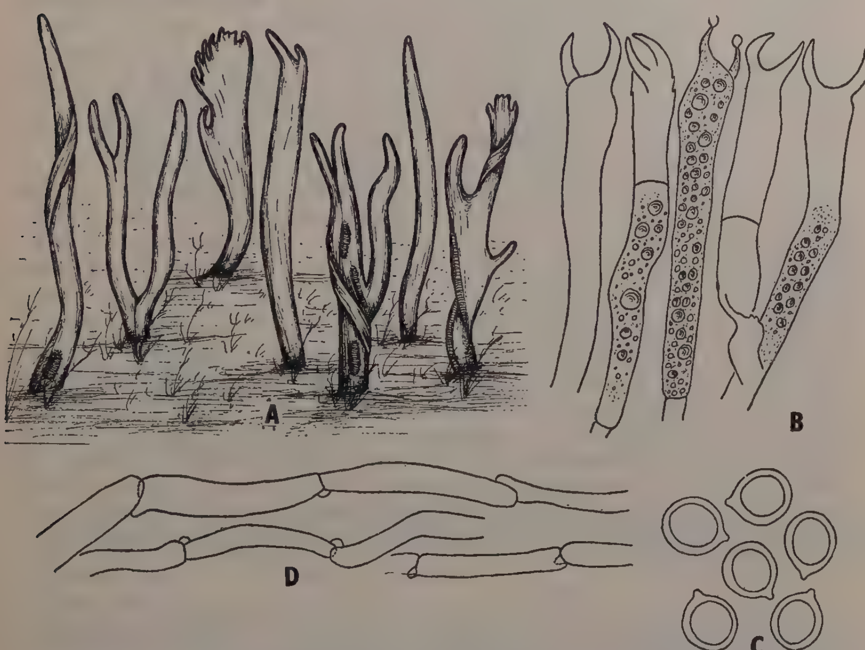
spathulate, simple, or irregularly branched, solid, or hollow when old, apex concolorous, acute, sterile; trunk 0·5–1·3 cm. × 1–4 mm., concolorous, small, indistinct, solid, cylindric or flattened, grooved and twisted, often connate, sterile, hyphæ of the stem often loosened out so as to give a hairy appearance when observed under the low power of the microscope; flesh white, unchanging; smell and taste inparticular. *Hymenium* spread all over except the sterile trunk and apices,



TEXT-FIG. 2. *Clavaria zollingeri* Lév. A. Fructification, ×1. B. Multiguttulate basidia, ×1,150. C. Basidiospores, ×1,150. D. Secondarily septate hyphæ, ×500.

thickening, up to 110 μ thick; subhymenium not differentiated from the medulla. *Basidia* 40–64 × 4·8–6·4 μ, cylindric-elongate, multiguttulate, becoming secondarily septate after spore discharge; sterigmata 2, strongly incurved, stout, 4–5·6 μ long. *Basidiospores* 6·4–8·4

$\times 5 \cdot 6$–$7 \cdot 2\,\mu$ hyaline, globose to subglobose, sometimes ovoid, papillate, papilla small, up to $0 \cdot 8\,\mu$ long, smooth, uniguttate, gutta large, filling almost three-fourth of the spore cavity. *Hyphæ* monomitic, 2–12 μ wide, hyphal cells 30–110 μ long, inflated, septa at short intervals, at longer intervals in some narrow uninflated hyphæ, cells of narrow hyphæ up to 200 μ long, slightly thick-walled, hyaline, convoluted, clamped, clamps at all septa, constricted almost at each septum (Text-Fig. 3, A-D.)



TEXT-FIG. 3. *Clavulina subrugosa* (Clel.) Corner. A. Fructifications, ×1. B. Basidia becoming secondarily septate after spore discharge, ×1,150. C. Uniguttate basidiospores, ×1,150. D. Clamped hyphæ, ×500.

Collected on soil amid mosses, Kempty Falls, Mussoorie, August 27, 1956, 281.

This fungus was observed growing very luxuriantly in the form of a regular crop spreading over sufficient area. It is quite common in the Mussoorie hills and comes very close to the meagre description of *Clavulina subrugosa* (Clel.) Corner. The description of the Mussoorie collection will apparently represent the species in future.

62. *Clavulinopsis corniculata* (Fr.) Corner 'haploid state'

Fructifications up to 7 cm. tall and up to $1 \cdot 5$ cm. broad, gregarious, cæspitose, with 2–12 fruit bodies, cæspitose clusters up to $3 \cdot 8$ cm.

broad, rarely solitary, erect, medium-sized, radial, trunk generally present, sometimes absent, sparsely branched, fleshy, smooth, glabrous, brownish yellow below, yellow above, on drying turning brown; trunk 0·5–3 cm. × 1–3 mm., radial, submerged portion covered over by white mycelial felt, hairy, sterile, exposed portion concolorous, smooth, fertile, the length of the portion covered over by mycelial felt depends upon the length to which the fruit body remains submerged in the dead leaf-mould; hyphæ of mycelial felt up to 2 μ wide, hyaline, slender, uninflated, non-septate, thick-walled; branching dichotomous, up to 5 times divided, branches regular, generally divaricate, equal to unequal, in alternating planes, cylindric, or flattened just below the region of bifurcation (where it may also be grooved); primary branches up to 3 mm. wide, radial; ultimate branchlets very short to very long, up to 2 cm. long, cylindric; apices acute, sterile, concolorous, bifid; flesh lighter concolorous, unchanging; taste slightly sweetish; smell like a meal or inparticular. *Hymenium* spread all over except the sterile portion below and the sterile apices, thickening, up to 80 μ thick. *Basidia* 40–56 × 4·8–7·2 μ, clavato-elongate, multiguttulate, guttules large and in a row; sterigmata 1–2, mostly 2, straight, sometimes slightly incurved or even outcurved, long, stout, 5·6–8·8 μ long. *Basidiospores* 6·4–8 μ wide, hyaline, globose, papillate, papilla prominent and not eccentric and up to 1·6 μ long, uniguttate, gutta large and filling up to three-fourth of the spore cavity. *Hyphæ* monomitic 1–6 μ wide, sometimes up to 8 μ wide, hyphal cells 16–160 μ long, cells of narrow hyphæ still longer, uninflated or only slightly inflated, yellow in a mass, pale ochraceous or subhyaline individually, irregular in outline, straight to convoluted and twisted, thin-walled to slightly thick-walled, branched, without clamps, septate, septa at short to long intervals, not secondarily septate, hyphal cells often gliding over one another. (Text-Fig. 4, A-D).

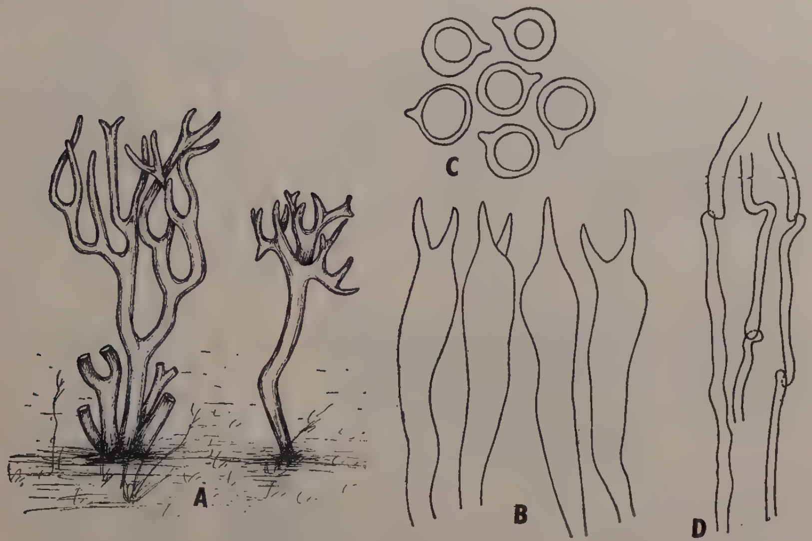
Collected on soil amid a thick layer of dead leaf-mould, The Park, Mussoorie, August 16, 1956, 282; on soil amid dead leaf-mould, Brewery Road, Mussoorie, August 29, 1956, 283.

The presence of 2-spored basidia and absence of clamps would indicate that these two Mussoorie collections belong to the genus *Clavulina*, which, however, possesses subcylindric basidia, eventually becoming septate and strongly curved sterigmata. The basidia in these two Mussoorie collections possess straight sterigmata and a long tapered base. These two Mussoorie collections come nearest to *Clavulinopsis corniculata* (Fr.) Corner, except that its basidia are 2-spored and the hyphæ are without any clamps. This is a second report [the first one being that of *Clavulinopsis fusiformis* (Fr.) Corner by Thind and Anand, 1956 *b*] of the absence of clamps in this genus and, likewise, it may also be correlated with the predominently 2-spored (or haploid) state of the fruit body.

63. *Clavulinopsis helvola* (Fr.) Corner

Fructifications 2·5–6·8 cm. long, gregarious, solitary, sometimes çæspitose (up to 4 clubs in a cluster), erect, small to medium-sized,

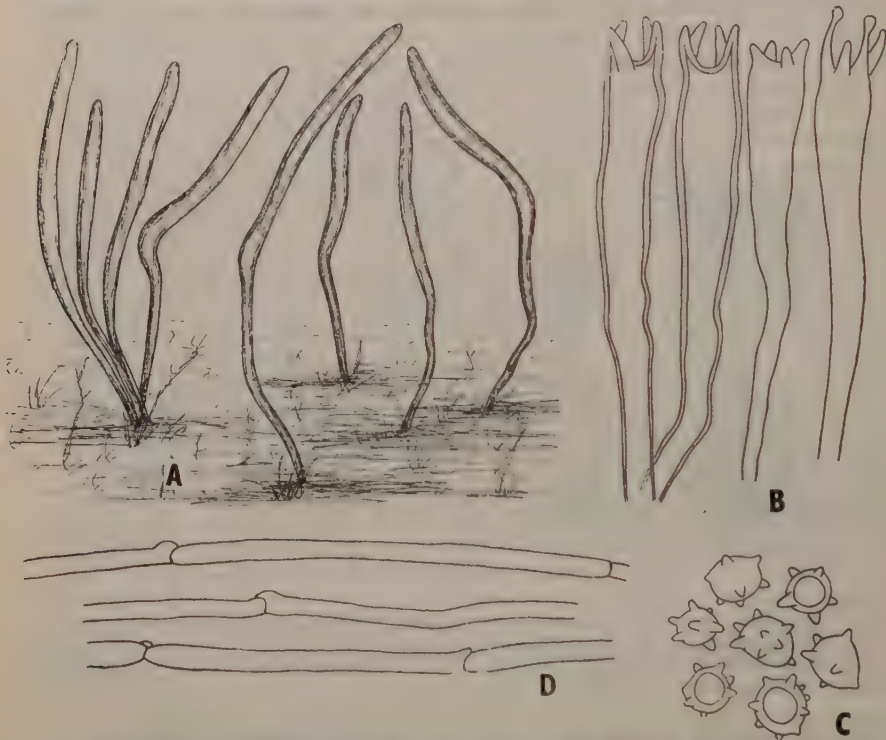
radial, trunk present, simple, rarely bifurcating at the top, cylindrical to clavate, fleshy, smooth, glabrous, deep bright yellow, on drying turning orange yellow; head 1·2–4·2 cm. × 0·5–2 mm., cylindric, straight to bent, hollow, apex obtuse, fertile, concolorous; trunk 1·5–2·7 cm. × 0·5–1 mm., distinct, lighter concolorous, narrower than the head,



TEXT-FIG. 4. *Clavulinopsis corniculata* (Fr.) Corner, "haploid state". A. Fructifications, ×1. B. Basidia with mostly 2, rarely 1, sterigmata, ×1,150. C. Uniguttate basidiospores, ×1,150. D. Hyphæ without clamps, hyphal cells often gliding over one another, ×500.

sterile, marked by compact layer of narrow longitudinal hyphæ 1 μ wide at the surface, surface hyphæ often becoming loosened as emergent hyphæ which become more loosened when preserved in formalin—alcohol, finely villous at the base with 1 μ wide, excrescent, slightly thick-walled hyphæ; flesh lighter concolorous to concolorous (*i.e.*, light yellow to yellow), unchanging; taste and smell inparticular. *Hymenium* spread all over the head, trunk sterile, not thickening, or very slightly thickening, up to 80 μ thick; subhymenium indistinct. *Basidia* 48–64 × 6–8 μ, clavato-elongate, with a long tapered base, subhyaline, often becoming thick-walled, wall up to 1 μ thick; sterigmata 4, straight to bent, 4·8–7·2 μ long. *Basidiospores* 4·4–6·4 × 4–5·2 μ (excluding the spines), light yellow to yellow, globose to subglobose to subangular, rather sparsely bluntly echinulate, spines 0·8–1·6 μ long and 0·8–1·2 μ wide at the base, rather stout and sparse with markedly blunt ends, uniguttate. *Hyphæ* monomitic, 1–6 (–10) μ wide, hyphal cells 30–180 μ long, uninflated, or slightly inflated, ochraceous to yellow in a mass, hyaline to subhyaline individually, thin-walled, branched, septate, septa at short to long intervals, not secondarily septate, clamped. (Text-Fig. 5, A-D.)

Collected on soil under Oak forest, Brewery Road, Mussoorie, August 14, 1956, 284; on soil under Oak forest, Brewery Road, Mussoorie, August 23, 1956, 285; on soil under Oak forest, Chakrata Toll, Mussoorie, September 5, 1957, 286.



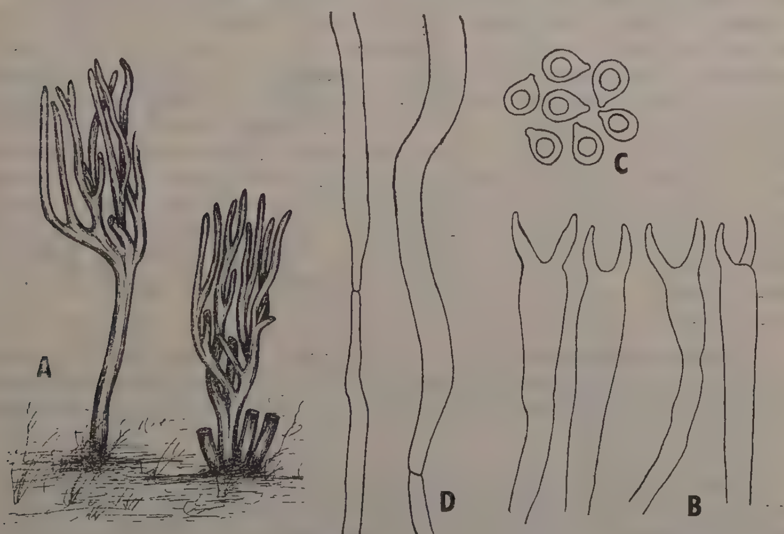
TEXT-FIG. 5. *Clavulinopsis helvola* (Fr.) Corner, A. Fructifications, × 1. B, Basidia often becoming thick walled, × 1,150. C. Bluntly echinulate basidiospores. × 1,150. D. Clamped hyphæ, × 500.

This species, though common in the Mussoorie hills, does not appear to grow there very abundantly or luxuriantly. It is at once recognized by the yellow colour, simple habit, and globose spores characteristically marked by large blunt spines rather sparsely arranged.

64. *Clavulinopsis subtilis* (Fr.) Corner

Fructifications up to 5·5 cm. tall and up to 1·2 cm. broad, densely gregarious to densely crowded, densely cæspitose with 3–8 fruit bodies, cæspitose cluster up to 2·5 cm. broad, erect, medium-sized, radial, trunk present, profusely branched, fleshy, smooth, glabrous, white or milk white, on drying turning brown; trunk 1–2·8 cm. × 1–3 mm., radial, sterile, finely hairy when seen under the low power of the microscope (most probably due to loosened out hyphæ), concolorous; branching dichotomous, up to 5 times divided, branches regular, equal

to unequal, in alternating planes, crowded and short when young, lower branches sterile, upper fertile, cylindric; primary branches up to 2 mm. broad, radial; ultimate branchlets very short in younger fructifications, very long in mature ones, up to 2·5 cm. long, cylindric; apices acute to subacute, sterile, concolorous, flesh white, unchanging; smell inparticular; taste mealy or inparticular. *Hymenium* spread only on the upper branches, the lower branches, trunk and apices are sterile, thickening, up to 110 μ thick. *Basidia* 24–36 $\times$ 3·2–4·8 μ, clavate; sterigmata 2, straight to slightly incurved, long, stout, 4·8–7·2 μ long. *Basidiospores* 4–4·8 $\times$ 3·2–4 μ, hyaline, globose to subglobose, papillate, papilla small, uniguttate, guttule small and occupying one-fourth or one-third of the spore cavity. *Hyphæ* monomitic, up to 12 μ wide, hyphal cells up to 320 μ long or even more, inflated, hyaline, thin-walled, without clamps, septate, septa at long intervals, mostly cells narrower at the septa, H-pieces present, sparsely branched. (Text-Fig. 6, A-D.)



TEXT-FIG. 6. *Clavulinopsis subtilis* (Fr.). Corner. A. Fructifications, $\times$1. B. Basidia with 2 sterigmata, $\times$1,150. C. Basidiospores, $\times$1,150. D. Hyphæ without clamps, $\times$1,150.

Collected on soil under Oak forest, The Park, Mussoorie, August 16, 1956, 287.

This Mussoorie fungus undoubtedly belongs to *Clavulinopsis subtilis* (Fr.) Corner. The most interesting thing about this fungus is that its basidia are always with 2 sterigmata and its hyphæ are without clamps. Hence it may be regarded as the haploid state of *C. subtilis*. The two sterigmata may be straight to slightly curved but the basidia are always clavate with a long tapered base as it is true of *Clavulinopsis*.

C. subtilis is closely allied to *C. dichotoma* (God.) Corner which, however, has branches somewhat thickened and compressed near the tips, not merely subulate, and slightly larger spores. Corner (1950) states that *C. dichotoma* is probably only a form of *C. subtilis*. *C. subtilis* is also very near to *C. biformis* (Atk.) Corner which, however, has narrower spores.

65. *Clavulinopsis tenuicula* (Bourd. *et* Galz.) Corner

Fructifications 6–10 mm. high, 0·5–5 mm. wide (including the branched portion), gregarious, singly, erect, small-sized, radial, or sometimes flattened, trunk present, simple to branched, fleshy, smooth, glabrous, white, later on turning greyish purple at the top especially in branched fructifications, simple, white fructifications turning light brown or cream coloured on drying, branched fructifications turning brown below and light greyish purple at the top; trunk $1–4 \times 0·3–0·5$ mm., cylindric, indistinct, white, sterile, smooth, appearing hairy due to loosened out hyphæ; branches few to many, up to 7 times branched, dichotomous, divaricate, unequal, in alternating planes; primary branches up to 0·8 mm. wide, cylindric to flattened; ultimate branchlets up to 2 mm. long, in pairs, rounded; apices acute, sterile; flesh white, unchanging; taste and smell inparticular. *Hymenium* spread all over except the sterile trunk and sterile apices, not thickening, up to 28 μ thick. *Basidia* $15–21 \times 3·6–4·4$ μ, clavate, small; sterigmata 4, small, straight, 2·4–4 μ long. *Basidiospores* $2·8–3·6 \times 2·4–2·8$ μ, hyaline, very small, subglobose to broadly ellipsoid, papillate, papilia small, smooth, uniguttulate, guttule filling one-third of the spore cavity.

Hyphæ monomitic, 2–6 μ wide, hyphal cells up to 240 μ long, uninflated, rarely inflated at places up to 10 μ wide, hyaline, branched, thin-walled, septate, septa at long intervals, clamped, clamps abundant. (Text-Fig. 7, A-D.)

Collected on decaying and rotting leaves of Oak, rotting twigs or wood of Oak under the thick shade in Oak forest, Spring Road, Mussoorie, August 23, 1957, 288; on decaying leaves of Oak and dead mosses under thick shade in Oak forest, Chakrata Toll, Mussoorie, September 5, 1957, 289.

These two Mussoorie collections undoubtedly belong to *Clavulinopsis tenuicula* (Bourd. *et* Galz.) Corner and are characterized by the humicolous habitat, simple to branched very small fructifications often becoming greyish purple at the top, divaricate branches, uninflated hymenium and hyphæ, small basidia, and very small basidiospores. In these characters they are very close to *C. subtilis* sensu Whem. (Pap. *Mich. Ac. Sci. Arts Letter* 20, 257, 1935) reported from Nova Scotia on moss or humus and which is included under *C. tenuicula* by Corner (1950).

C. tenuicula is very much similar to *C. minutula* (Bourd. *et* Galz.) Corner and differs from the latter only in the slightly larger spores

($2 \cdot 5$–$3 \times 2 \cdot 5$–$2 \cdot 8\,\mu$ in *C. minutula*). Thus the two are hardly distinguishable. According to Corner (1950), both *C. tenuicula* and *C. minutula* are, perhaps, diminutive uninflated derivatives of *C. subtilis* (Fr.) Corner, unless the narrow hyphæ indicate affinity with *C. propera* (Bourd.) Corner.

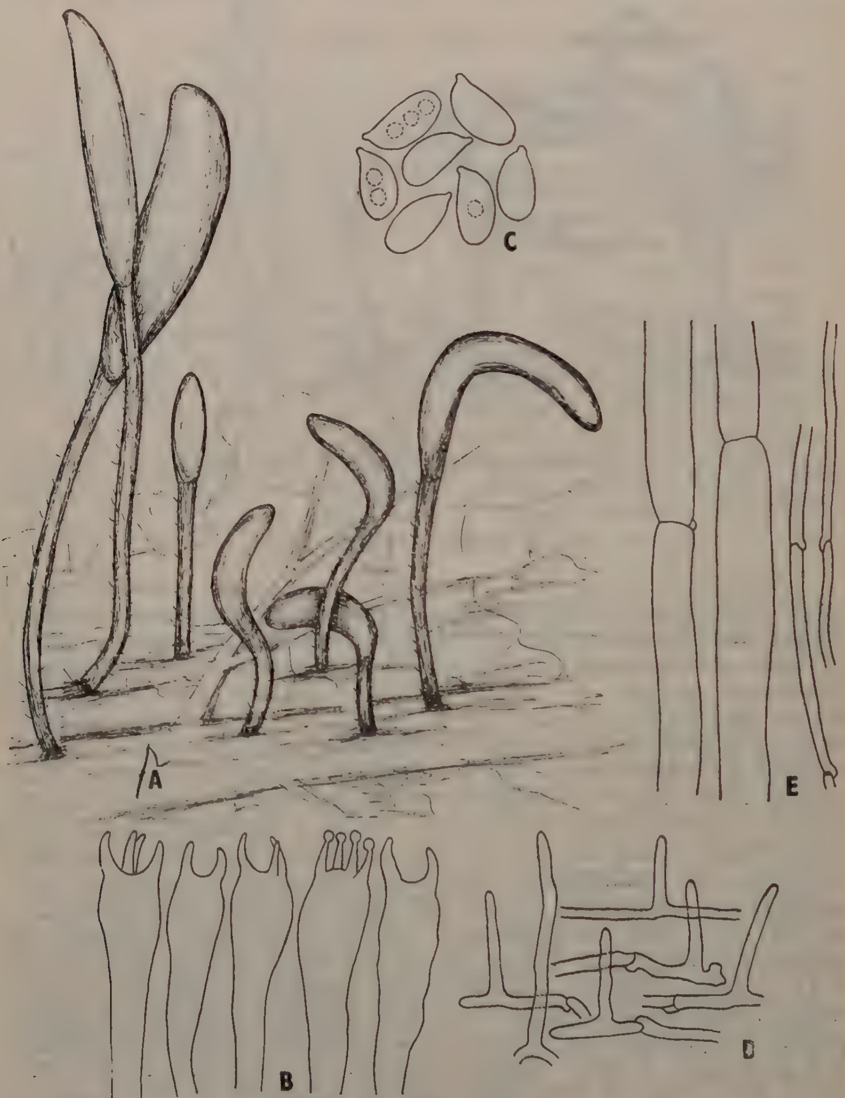
TEXT-FIG. 7. *Clavulinopsis tenuicula* (Bourd. *et* Galz.) Corner. A. Fructifications, $\times 6$. B. Basidia, $\times 1{,}150$. C. Basidiospores, $\times 1{,}150$. D. Clamped hyphæ, $\times 500$.

66. *Pistillaria setipes* Grev.

Fructifications up to $6 \cdot 5$ mm. long, gregarious, scattered, erect, small-sized, radial, trunk present, simple, not arising from sclerotium, fleshy, smooth, glabrous, white, on drying turning deep cream coloured to light yellow; head $0 \cdot 6$–$4 \cdot 5 \times 0 \cdot 23$–$0 \cdot 7$ mm., small to long, white, cylindrical, straight to bent, narrower at the top, apex rounded or obtuse and fertile; trunk $0 \cdot 8$–$2 \cdot 7 \times 0 \cdot 12$–$0 \cdot 15$ mm., slender, distinct, much narrower than the head, transparent, cylindric, sterile, sparsely marked by caulocystidia, the base minutely erumpent; caulocystidia arising from narrow, uninflated, outermost agglutinated longitudinal hyphæ, simple, hyaline, non-septate, straight, narrowed upward but apex obtuse, mostly up to $50\,\mu$ long, sometimes up to $80\,\mu$ long, and up to $4\,\mu$ wide, thin-walled; flesh white, unchanging; smell and taste inparticular. *Hymenium* spread all over the head, not thickening, up to $40\,\mu$ wide; subhymenium up to $18\,\mu$ wide, composed of thin-walled, interwoven hyphæ, up to $4\,\mu$ wide. *Basidia* 28–$36 \times 7 \cdot 2$–$8 \cdot 8\,\mu$, clavate, hyaline; sterigmata 2–4, straight to incurved, 4–$6 \cdot 4\,\mu$ long. *Basidiospores* 8–$9 \cdot 6 \times 4 \cdot 4$–$5 \cdot 2\,\mu$, hyaline, ellipsoid, papillate, papilla conspicuous and up to $0 \cdot 8\,\mu$ long, smooth, aguttate, or vaguely 1–4 guttules in a row. *Hyphæ* monomitic, 6–$20\,\mu$ wide, hyphal cells up to $340\,\mu$ long, or even more, inflated, uninflated at the surface of the trunk (1–$4\,\mu$ wide), thin-walled, hyaline, rarely branched, longitudinal, septate, septa at long intervals, narrow uninflated hyphæ clamped, inflated hyphæ rarely clamped. (Text-Fig. 8, A-E.)

Collected on dead and decaying leaves of a composite under the thick shade of the flowering plants, The Municipal Garden, Mussoorie, September 11, 1956, 290; same flowering bed, August 28, 1957, 291.

This Mussoorie fungus undoubtedly belongs to *Pistillaria setipes* Grev. Its caulocystidia are always simple and it has been collected



TEXT-FIG. 8. *Pistillaria setipes* Grev. A. Fructifications, ×20. B. Basidia, ×1,150. C. Basidiospores, ×1,150. D. Caulocystidia, ×500. E. Clamped hyphæ, narrow uninflated hyphæ from the surface of the trunk, ×500.

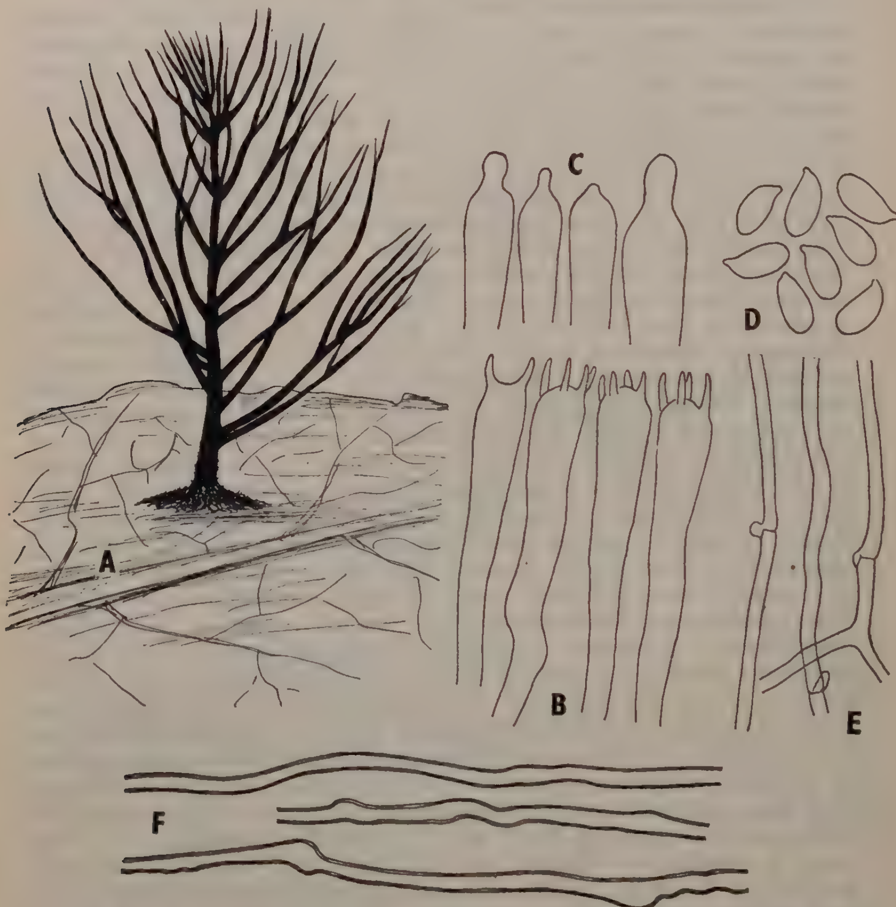
only on the dead and decaying leaves of a herbaceous plant of Compositæ.

67. *Pterula verticillata* Corner

Fructifications up to 3 cm. high, up to 1·8 cm. broad, densely gregarious, solitary, or cæspitose, often crowded and entangled together or connate in large masses, erect, monopodially branched, small-sized, trunk present, fleshy-tough, smooth, glabrous, white above and light brown below, on drying turning brown and tough (or leathery) with the hymenium shrivelled up like a broken skin on the hard axis (observed under the low power of the microscope); trunk 1–5×0·5–1·2 mm., distinct, small, covered over with very slender protruding out hyphæ especially near the base, rarely marked by strigose hair at the base, often subdiscoid at the base from which are always given out shortly spreading. dirty whitish fibrils attaching the fructifications with the decaying leaves and dead twigs; disc-like base sterile and composed of generative and skeletal hyphæ; fine mycelial fibrils composed of thin-walled generative hyphæ 1–3 μ wide and without any skeletals; branching monopodial, pseudoverticillate, *i.e.*, singly to somewhat whorled, the main axis giving out 2–5 tiers of 3–5 branches, also giving out numerous filiform lateral branches, sometimes tiers condensed and indistinct, branches slender, often connate due to crowding, radial, in alternating planes, unequal, main branches in alternating tiers, 0·3–0·8 mm. wide, terete; branchlets 0·2–0·5 mm. wide, curved ascending, simple or rarely once or twice dichotomously branched, rather lax, tapering very gradually to hair-like tips 4–45 μ wide,; apices composed of a sheaf of parallel hyphal tips 2–3 μ wide, tapering to a fine thread; flesh concolorous, unchanging, taste slightly bitter or none; smell inparticular. *Hymenium* unilateral, spread all over one side of the trunk and branches, sterile at the top, thickening, up to 114 μ thick; sterile sides of the stem and branches covered with protruding out slender, narrow, thin-walled branched hyphæ. *Cystidia* absent from the hymenium; however, tips of some apparently sterile basidia marked by a single subglobose spore-like body 2–3·5 μ wide, or tips simply very much narrowed, sterile basidia protruding up to 22 μ beyond the hymenium. *Basidia* 30–40×5·6–7·2 μ, clavate; sterigmata 4, sometimes 2, straight to slightly incurved, 3·2–4·8 μ long. *Basidiospores* 5·6–7·2×2·4–3·6 μ, hyaline, ellipsoid, smooth, papillate, papilla distinct and up to 0·8 μ long, aguttate. *Hyphæ* dimitic, skeletal hyphæ 2–5 μ wide, brownish, smooth, thick-walled, wall up to 0·6 μ thick, uninflated, unbranched, longitudinal, aseptate, often kinked and of uneven width, always with a wide lumen, not clamped; generative hyphæ 2–4 μ wide, hyaline, thin-walled, uninflated, septate, septa at very long intervals, clamped; hyphæ intermediate between the skeletal and generative hyphæ also present and these connect the former with the latter. (Text-Fig. 9, A-F.)

Collected on dead twigs, decaying leaves and dead needles, under a mixed forest, Kana Tal, Mussoorie, August 21, 1956, 292.

This Mussoorie collection undoubtedly belongs to *Pterula verticillata* Corner and is easily recognized by its characteristic monopodial, more or less verticillate branching, fibrillose spreading and attaching branches given out from the base, light coloured fructifications white



TEXT-FIG. 9. *Pterula verticillata* Corner. A. Fructification, ×2. B. Basidia ×1,150. C. Sterile basidia, ×1,150. D. Basidiospores, ×1,150. E. Clamped generative hyphæ, ×500. F. Thick-walled skeletal hyphæ, ×500.

at the top, lignicolous or humicolous hab'it, and $6–7 \times 2 \cdot 5–3 \cdot 5\ \mu$ basidiospores. The stem or trunk of the fructifications is not much strigose and does not possess caulocystidia as reported for the species. Besides, the hymenium appears to be regularly unilateral. The sterile hymenium and the caulocystidia as depicted in Text-Fig. 239 by Corner (1950) were not observed.

Acknowledgments

The authors are deeply indebted to Mr. E. J. H. Corner, F.R.S., of the Botany School, Cambridge, England, for help in the identification of the species and valuable suggestions and Prof. P. N. Mehra, Head of the Panjab University Botany Department, for providing facilities and encouragement. They are also thankful to Mr. B. Khanna for his help in making the illustrations of the fructifications.

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CARBON-NITROGEN METABOLISM OF SOIL-FUNGI

VIII. Mechanism of Nitrate Utilization in *Fusarium vasinfectum*

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(Received for Publication on May 7, 1958)

The ability of *Fusarium vasinfectum* to metabolise various carbon and nitrogen sources and grow in media of varying hydrogen-ion concentration has been shown in earlier parts (Natarajan, 1958 *a*). Since all nitrogen sources end up as amino nitrogen in cell proteins, reduction is an essential step. The mechanism of nitrate nitrogen utilization and the various intermediate stages are presented in this paper.

Materials and Methods

The strain of *Fusarium vasinfectum*, the cultural methods and composition of the medium are the same as in earlier parts. The carbon sources are sucrose and glucose. With each carbon source, sodium nitrate, ammonium nitrate and ammonium sulphate formed separately the nitrogen source. Equivalent quantities of carbon and nitrogen sources are used at the optimum C: N ratio reported earlier. *F. vasinfectum* is grown with and without the addition of vitamin B_1 and KCN separately.

Pyruvic acid estimated by the method of Friedemann and Haugem (1938) and ethyl alcohol estimated by the method of Sciarini and Wirth (1945) are reported for various periods in Table I.

Discussion

It can be readily seen that the greater accumulation of pyruvic acid takes place in the presence of nitrate contrasting with smaller quantities when ammonium sulphate is the nitrogen source. This feature is noticeable irrespective of carbon sources. The accumulation of pyruvic acid has thus to be related to the reduction of nitrate to nitrite. In the presence of vitamin B_1 hydrochloride, however, the amount of pyruvic acid accumulated in the control is greater than vitamin supplemented medium. The inhibitory effect of nitrite ions produced by the reduction of nitrate appears to be compensated by the addition of thiamin. Further this addition appears to influence the reaction by the decarboxylating system of the organism. When

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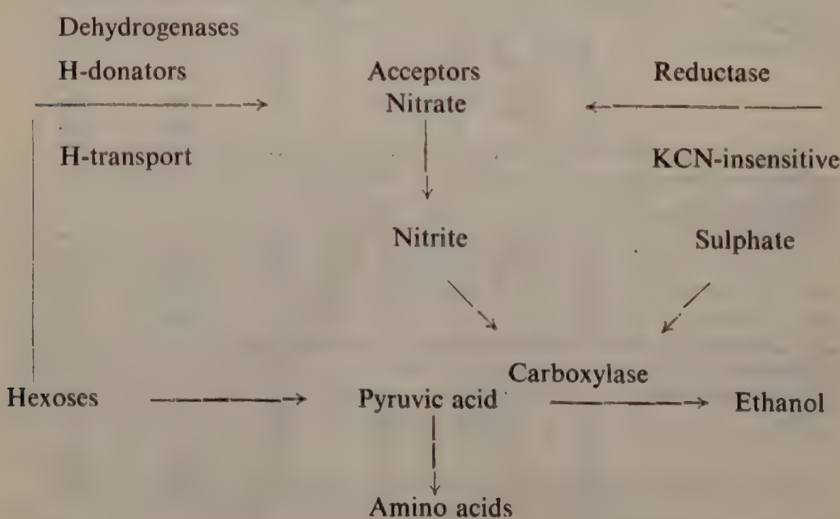
TABLE I

Variation of the formation of pyruvic acid and ethanol by F. vasinfectum *under different conditions*

Medium	Age (days)	Pyruvic acid (mg.)			Ethanol (mg.)	
		Blank	In presence of		Blank	In presence of KCN 2 mg./50 ml.
			Vitamin B_1 20γ/50 ml.	KCN 2mg./50ml.		
Sucrose—Sodium nitrate	2	4	..	6	..	..
	4	148	18	140	..	..
	6	168	24	170	..	..
	8	150	18	152	350	330
	10	..	..	..	400	390
	12	..	..	..	360	330
Sucrose—Ammonium nitrate	2	7	..	7	..	..
	4	151	15	146	..	..
	6	175	25	179	..	..
	8	160	20	158	370	375
	10	..	..	..	410	400
	12	..	..	..	380	350
Sucrose—Ammonium sulphate	2	..	..	..	..	..
	4	20	19	21	..	..
	6	25	22	24	..	..
	8	19	30	20	160	157
	10	..	..	..	200	210
	12	..	..	..	180	170
Glucose—Sodium nitrate	2	4	..	5	..	..
	4	120	15	125	..	..
	6	150	21	146	..	..
	8	118	20	110	340	350
	10	..	..	..	410	390
	12	..	..	..	390	380
Glucose—Ammonium nitrate	2	6	..	5	..	..
	4	110	18	112	..	..
	6	140	20	146	..	..
	8	110	16	115	370	360
	10	..	..	..	440	450
	12	..	..	..	400	410
Glucose—Ammonium sulphate	2	..	..	..	..	..
	4	15	12	16	..	..
	6	22	26	20	..	..
	8	20	21	15	150	160
	10	..	..	..	160	158
	12	..	..	..	150	152

the amount of pyruvic acid accumulated had reached a maximum, the ratio between the amounts in the vitamin supplemented and non-supplemented medium is 1 to 7. It has been shown earlier (Natarajan, 1958 *b*) that nitrite was being formed during the course of fermentation of carbohydrates and nitrates; because of the accumulation of pyruvic acid in nitrate medium, the inhibitory action of nitrite on NH_2 group of the carboxylase system present may be inferred. Further when ammonium nitrate was used it has been noticed that nitrate ions are apparently preferentially used (Natarajan, 1956 *a*, *b*). And, irrespective of carbon sources, the formation of pyruvic acid depends on the formation of nitrite ions because, with ammonium sulphate only very small quantities were found. Further the amount of pyruvic acid formed was of the same magnitude when sodium nitrate and ammonium nitrate were used as nitrogen source; however ammonium nitrate gave slightly higher yields of ethyl alcohol. Ammonium sulphate is a less satisfactory source of nitrogen with respect to the formation of ethanol. Since dehydrogenases are present in *Fusarium* species, nitrates become hydrogen acceptors. Ammonium sulphate and nitrite in turn serves to block the functioning of the carboxylase system. The limited accumulation of pyruvic acid and the partial functioning of the carboxylase system involve a competition between the nitrite or sulphate inhibited and the free enzyme indicating that the nitrate-nitrite reaction proceeds at a faster rate than the reduction of nitrite to hydroxylamine. Therefore the nitrate→nitrite reduction may ensue from two reactions: (*a*) by the action of H_2 freed by the dehydrogenase and carried over the acceptor nitrate from hydrogen donors formed in the course of initial degradation of carbohydrate present; (*b*) by the action of KCN insensitive nitrate reductase (Natarajan, 1958 *b*). It can be seen from Table I that there is no difference in the pyruvic acid and ethyl alcohol values of blank and KCN added medium. The mechanism can therefore be represented as follows:—



Summary

Striking accumulation of pyruvic acid taking place in the presence of nitrate, contrasting with smaller quantities when ammonium sulphate is the nitrogen source is related to reduction of nitrate to nitrite. The mechanism of nitrate utilization in *Fusarium vasinfectum* is investigated.

Acknowledgment

I am very grateful to Professors Dr. S. V. Anantakrishnan, Head of the Department of Chemistry, Madras Christian College, Tambaram and Dr. T. S. Sadasivan, Director, University Botany Laboratory, Madras, for their guidance and encouragement.

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STUDIES IN THE ORDER PIPERALES

II A Contribution to the Study of Vascular Anatomy of the Flowe of *Peperomia*[1,2]

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(Received for publication on June 4, 1958)

Introduction

A perusal of literature on the subject reveals that the ovule of *Peperomia* is generally considered as basal and the gynæceum as monocarpellary. Doubt has been expressed by Puri (1951, 1952) regarding the basal condition of the ovule in *Peperomia* as well as in some other genera of other families. This has since been confirmed in a preliminary study (Murty, 1952). Further, the structure of the stigma does not appear to fit in with the monocarpellary concept. It was, therefore, thought necessary to check up and establish if possible the correct nature of the ovule and gynæceum in *Peperomia* with the help of floral anatomy and comparative morphology.

Material and Methods

Of the twenty species of *Peperomia* studied, only a few species were collected by the author from different places—Dehra Dun (*P. pellucida*), Bangalore (*P. sandersii* var. *argyreia*, *P. argyreia*) and Kodaikanal and Ootacamund (*P. reflexa*) while the material of a majority of them, was collected by Prof. V. Puri from hot houses when he was on a study tour of the U.S.A. and Europe. Prof. Puri collected *P. cniapas*, *P. sandersii*, *P. prostrata*, *P. sp.*$_1$, *P. sp.*$_2$, *P. sp.*$_3$ and *P. sp.*$_4$ from the Botanical Garden, Cornell University, Ithaca, N.Y.; *P. blanda*, *P. fenzlei*, *P. incana*, *P. rubella* and *P. magnoliæfolia* from Bergianska Botanical Garden, Stockholm; and *P. fraseri* from Botanical Institute, Kiel. Material of *P. reflexa* was collected and fixed in F.A.A. at the author's request by V. Raghavan (Gauhati); *P. comarapana* by Dr. A. Burkart (Parana, Buenos Aires) and *P. prostrata* by Dr. K. Subramanyam (then at Cornell University, Ithaca, N.Y.). Some paraffin embedded material and prepared slides of *P. peirescifolia* and *P. metallica* were very kindly spared for me by Dr. O. Hagerup.

All material was fixed in F.A.A. and after dehydration embedded in paraffin and was cut into serial transverse and longitudinal sections

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[1] Based on a portion of a thesis accepted for a Ph.D. Degree of the Agra University.

[2] Research contribution No. 14 from the School of Plant Morphology, Meerut College, Meerut.

8–12 microns thick. Various stain combinations were tried, but crystal violet and erythrosin gave the best results for floral anatomy.

Observations

External Morphology.—The flowers are arranged on a spike which is terminal, axillary or leaf opposed. In a majority of species the spike is simple, somewhat fleshy, cylindrical and varies in length from a few to 24 cm. Out of the species studied the longest spikes have been observed in *P. argyreia* and the smallest in *P. rubella*. The lower part of the spike is sterile and forms a cylindrical stalk. An abnormal spike which is forked at the apex has been seen in *P. reflexa*, a condition also reported in *P. junghuniana* by Costerus and Smith (1905). Though in general the spikes are solitary, in a few cases they are numerous and paniculate (*P. fraseri*, *P. sandersii* var. *argyreia*) or umbellate (*P. umbellifera*).

The flowers are minute, sessile and arranged acropetally and spirally on the surface of the infloresence axis. In a few species (*e.g.*, *P. reflexa*, *P. magnoliæfolia*, *P. argyreia*, *P. sp.*$_1$ and *P. sp.*$_2$) they appear to be situated in small pits on the inflorescence axis. The borders of these cup-like pits constitute ridges separating the flowers. In *P. argyreia* (Text-Fig. 1), *P. magnoliæfolia* (Text-Fig. 26) and *P. sp.*$_2$ (Text-Fig. 44) some axial tissue of the spike grows out in between the bract and the flower and looks like a finger-like projection in a longitudinal section. The bract which is thus separated from its axillant flower, is also placed in a depression (Text-Fig. 2). The flowers are commonly crowded on the axis of the inflorescence but in *P. pellucida* and in the lower part of the spike in *P. comarapana* they are very sparsely arranged. Each flower is hermaphrodite and is invariably subtended by a peltate bract (Text-Figs. 2 and 3). It has two laterally placed stamens, each bearing a bilocular anther (Text-Figs. 3 and 4). The ovary is unilocular with a single unitegmic orthotropous ovule, usually described as basal. The single occasionally cleft stigma is described as lateral and brush-like. A distinct style is reported in some species (Trelease, 1921) while in others the stigmatic papillæ are just sessile.

Anatomy of the Inflorescence.—The anatomy of the lower sterile stalk-like part of the spike and the upper flower bearing region is similar in all the species examined. The epidermis is thin-walled in the flowering region but in *P. reflexa* it is comparatively strongly cuticularised. Stomata, which resemble in their structure, especially in the presence of upper ledges, with those occurring on vegetative parts, are occasionally seen in *P. pellucida*. Hydathodes and trichomes characteristic of the species also occur on the peduncle (Murty, 1958). A transverse section of the peduncle shows below the epidermis parenchymatous cortex with more or less large intercellular spaces. When there are large intercellular spaces as in *P. comarapana*, *P. argyreia* and *P. blanda*, the tissue appears to be spongy in nature. Chloroplasts and oil cells occur in this region of *P. reflexa*. A definite central pith is observed in *P. incana* and *P. sp.*$_2$

The vascular bundles of different species are closed and collateral like those occurring in the internode (Murty, 1958). However, they show some variation in their number and arrangement. They may vary from one [occasionally in *P. pellucida*, *P. hispidula* (Johnson, 1914)] to twenty or more, for instance 1–6 in *P. pellucida*; 2–3 in *P. rubella*; 3–4 in *P. fenzlei*; 4 in *P. comarapana* and *P. fraseri*; 4–6 in *P. reflexa*; up to 6 in *P. prostrata*; 6–8 in *P. blanda*; 6–12 in *P. cniapas*; 9–10 in *P. sandersii* var. *argyreia*; 12 in *P. sp.*$_2$ and 15 in *P. sp.*$_1$; 15–20 in *P. incana*; 17–20 in *P. sandersii*; about 20 in *P. magnoliæfolia* and more than 20 in *P. argyreia*. It is significant to note that more than eight bundles are usually met with in species showing alternate leaves and stouter spikes. They occur in a single ring in a majority of the species *e.g.*, *P. comarapana*, *P. fraseri*, *P. fenzlei*, *P. rubella*, *P. magnoliæfolia* and *P. incana*. An additional central bundle is observed in *P. sandersii* var. *argyreia*. *P. argyreia* has vascular bundles arranged in two rings while *P. sandersii* shows in addition to the two rings a central bundle also. A distinction between *P. sandersii* var. *argyreia* and *P. sandersii* is thus well brought out by anatomical studies of the spike.

Branching of Inflorescence.—Though a majority of the species show a simple spike, a few species *e.g.*, *P. fraseri*, *P. sandersii* var. *argyreia* have branched inflorescence like a panicle. *P. fraseri* further differs from the rest of the species studied in that it does not possess the characteristic cylindrical spike. Each branch of the panicle is very minute and arises from the axil of a minute leafy bract. The flowers are loosely arranged at the tip leaving a small sterile stalk at the base. The central axis of the inflorescence terminates in a few flowers. The anatomy of the main inflorescence axis resembles that of an internode. There are about 9 peripheral and 4–6 central bundles. The latter show fusion and splitting during their course through the inflorescence axis. Just below the place of attachment of the inflorescence bract, one peripheral and two corresponding central bundles, increase somewhat in size. The peripheral bundle is pinched off as it were as a trace that diverges out obliquely through the cortex and enters the bract of the inflorescence while the two central bundles constitute the supply of the axillary branch. The remaining stelar bundles reorganise again into peripheral and central bundles.

The branched inflorescence of *P. sandersii* var. *argyreia* is generally described as a panicle or catkin (Bailey, 1949, 1950). No anatomical studies appear to have been made so far to find out the real position. It is, therefore, dealt with here at some length. Externally the inflorescence axis shows one or two nodes separated by long internodes. At each node there is a conspicuous leafy structure (scale) enclosing one or two small scaly structures and one or two stalked spikes.

The main inflorescence axis has 10–14 collateral and normally oriented bundles arranged in two rings (Text-Fig. 5). On approaching a node, the bundles show anastomosing and branching and then a little higher up one of them diverges out into the cortex (Fig. 6). This is

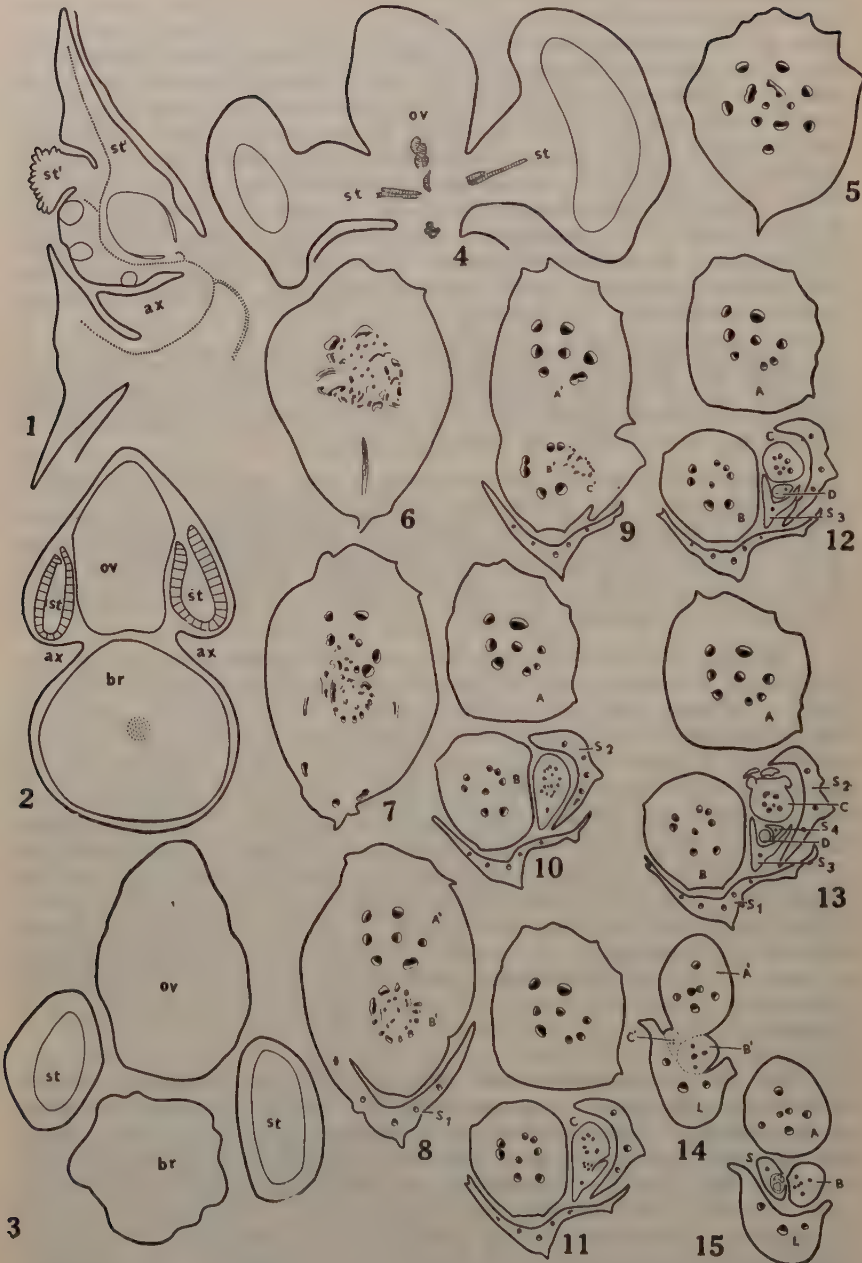
the median trace of the first scale. It is followed by four more lateral traces, two on either side (Text-Fig. 7). These five traces diverge out into the base of the scale that separates off soon after (Text-Fig. 8, S_1). The remaining bundles at the node organise into two groups A′ and B′. The one (B′) next to the supply of first scale consists of many small bundles while the other (A′) away from it has 7–8 bundles out of which one is central (Text-Fig. 8). They constitute respectively the vascular supplies of the axillary branch (B) and the main axis (A). From group B′ three traces (Text-Figs. 9 and 10) which may divide further move out as supply for another scaly structure—S_2. These are followed by some more traces that divide forming a cylinder for the axillary branch C which separates off along with the subtending scale S_2 (Text-Figs. 10 and 11).

Another scaly structure S_3 which receives a single trace separates off from the branch C (Text-Figs. 11 and 12), and this subtends the axillary branch D (Text-Fig. 12) and yet another minute scale S_4 (Text-Fig. 13) separates off from the latter.

Thus at a node on the inflorescence axis there are, in addition to the main axis (A) which may continue growth or end in a spike, three more branches enclosed within the first scale S_1. The branches B, C, D which end in spikes are subtended respectively by the scales S_1, S_2 and S_3 (Text-Fig. 13). These branches show some variation in the number of vascular bundles.

Though not having so elaborate a branch system as the last species, *Peperomia pellucida* commonly bears more than one spike at a flowering node. Of these one is invariably opposite to the leaf and the others are by its side. Occasionally the lateral spikes may be carried up and placed on a small 1–2-leaved branch. On a close examination of a flowering node some minute scale leaves have been observed. They are yellowish and cordate with an acute tip. On a young flowering node there are just present one leaf, one leaf opposed spike and one axillary bud, but in older ones or those towards the base there may be additional scale leaves with a corresponding number of axillary buds. Occasionally one of the scale leaves is green, comparatively broad and very conspicuous. A careful study of the external morphology of such a node of *P. pellucida* revealed that the different branches do not belong to the same node but that they represent a condensed branch system.

Just like a vegetative node (Murty, 1958) the flowering node of *P. pellucida* also shows some enlargement, branching and anastomosing of the bundles. Three of these then diverge out as leaf traces. They are followed by some more traces that constitute the axillary branch supply. The rest of the bundles reorganise and remain in the main axis. In one of the simplest flowering nodes it is seen that one bundle diverges out from those of the axillary branch (B′) towards one side and soon divides into 3–4 bundles. These constitute the vascular supply of the branch C subtended by a scaly structure (S) possessing a single bundle (Text-Figs. 14 and 15). Thus there are at a node



TEXT-FIGS. 1-15.

TEXT-FIGS. 1–15. Fig. 1. L.S. of flower of *P. argyreia* showing the course of vascular supply. Fig. 2. Tangential section of inflorescence of *P. argyreia* showing the arrangement of bract, stamens and ovary. Note that all these structures are surrounded by projecting tissue of the inflorescence axis and the axial tissue in between the bract and flower. Fig. 3. Tangential section of inflorescence of *P. pellucida* showing the position of bract; stamens and ovary. Fig. 4. Flower of *P. pellucida* showing vascular supply to stamens and ovary. Figs. 5–13. Serial cross-sections of node of an inflorescence of *P. sandersii* var. *argyreia* showing the mode of branching. Figs. 14 and 15. Serial cross-sections of a flowering node of *P. pellucida* showing formation of a branch of the second order.

A, main axis; *ax*, axial tissue; *B*, *C* and *D*, branches; *A′*, *B′*, *C′*, steles of branches *A*, *B*, *C*; *br*, bract; *L*, leaf; *ov*, ovary; S, S_1, S_2, S_3, S_4, scale leaves; *st*, stamen; *st′*, receptive stigma; *st″*, sterile stigma.

Figs. 1–2, ×56; Fig. 3, ×234; Fig. 4, ×147; Figs. 5–15, ×11.

three groups of bundles supplying 3 axes of which one is the main axis and the other two are branches.

In another instance 4 branches were observed to emerge out from the node. This resembles in anatomy the node just described above. But in this case the bundles of group 'C′' may also undergo some branching and then give off one bundle which on reaching the periphery divides into about four forming group '*d*″' and supply to the second scale leaf (Text-Figs. 16 and 17). The remaining bundles of group 'C″' constitute the vascular supply of another axis. Thus in this instance there are four axes corresponding to groups A′, B′, C′ and *d*′, one leaf and 2 scale leaves. One (B) or two (B and C) of these axes continue the vegetative growth while the others are modified into spikes either immediately (A and *d*) or after giving rise to one or two leaves (C).

The Flower.—All the twenty species of *Peperomia* studied here showed a single vascular branch, given off from the main supply of the axis in the direction of a flower. This branch generally traverses more or less horizontally (Text-Figs. 18 and 19) or as in *P. fraseri* obliquely upwards through the cortex of the axis or horizontally in young inflorescence and obliquely upward in the older ones as in *P. incana* (Text-Fig. 20) and *P. cniapas* (Fig. 21). In *P. sandersii* there is some descending down in the course of this bundle (Text-Fig. 22). Occasionally in *P. sandersii* var. *argyreia* the bundle first descends down obliquely and then ascends up to the base of the flower (Text-Fig. 23). In all the species examined this branch then splits up into two, one for the bract and the other for the flower. Rousseau (1927), however, remarks that the flower and the bract traces arise separately. The courses of these branches differ somewhat with the age of the spike also. In *P. reflexa* both the bract and flower traces run obliquely for some distance within the cortex of the spike (Text-Fig. 24).

The bract and the floral supplies separate off from each other at varying distances from the parent stele. These variations are more pronounced in *P. sandersii* (Text-Fig. 25), *P. magnoliæfolia* (Text-Fig. 26), *P. argyreia*, etc. where the axis is between the bract and its axillary flower, grows with age. In older spikes of *P. sandersii* var. *argyreia* (Text-Fig. 23) and *P. sandersii* (Text-Fig. 25) where the bract is far

removed from its axillary flower, the bract trace descends down parallel to the surface of the axis of the spike and then enters the bract.

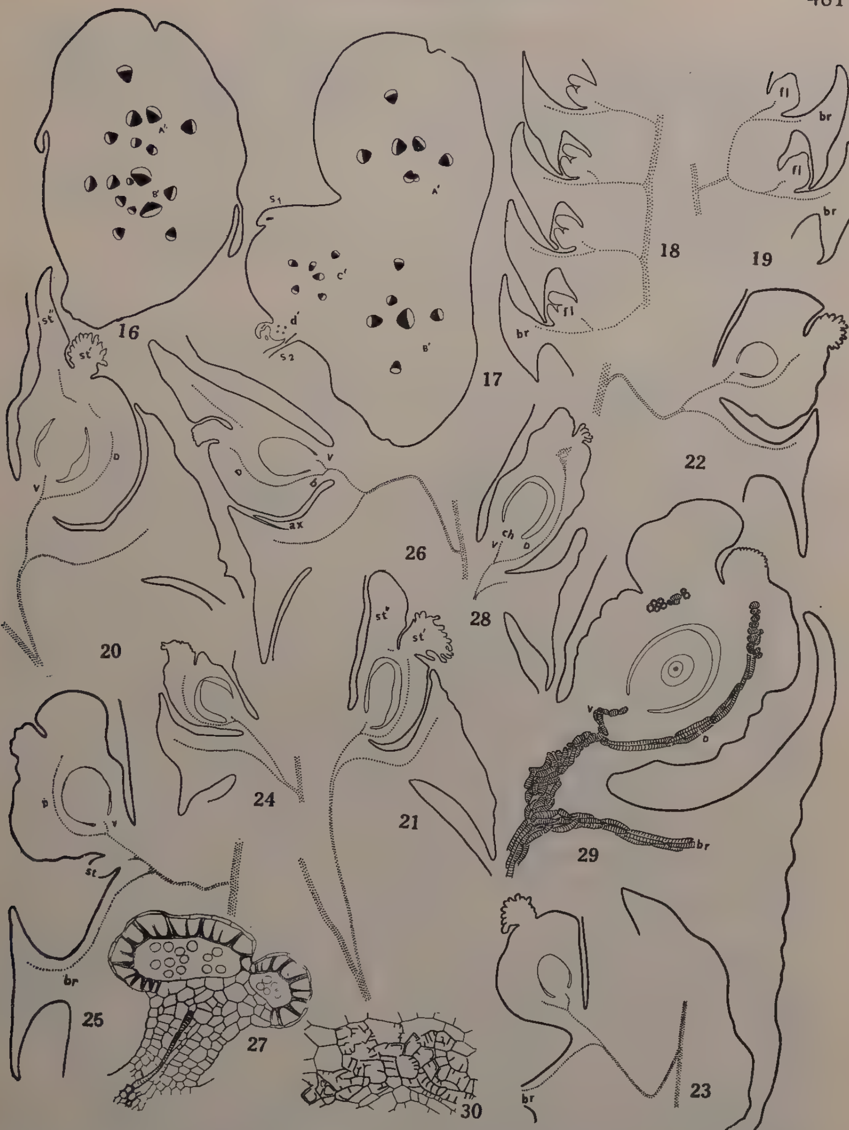
An abnormal course has been observed in *P. magnoliæfolia* where a single bundle derived from the parent stele runs horizontally to the periphery of the cortex where it bifurcates. The resulting two branches instead of supplying a bract and its axillary flower supply two distinct flowers and their subtending bracts. One of the branches ascends up and the other descends down to supply the respective organs (Text-Fig. 19) of the two flowers.

The floral supply immediately after entering the base of the flower gives off laterally two stamen traces that traverse undivided through their respective filaments (Text-Figs. 4 and 27).

The remaining vascular tissue divides at the base of the ovary into two unequal branches (Text-Fig. 28). The larger of these passes through the abaxial side of the ovary wall and forms a plate of tracheids at the base of the stigma where it disappears (Text-Figs. 28–30). This is apparently the dorsal bundle of the carpel. In two of the flowers of *P. comarapana*, a few tracheids have been seen separating from this branch at its base (Text-Figs. 31 and 32). A feature which attracts some attention in *P. magnoliæfolia* is the occurrence of a sharp bend in the course of this bundle immediately above its separation from its sister branch (Text-Figs. 26 and 33 *b*). This is a usual feature in this species and at one time it was supposed that it may give some clue as to the occurrence of some additional floral organs (carpels in the flower), but no conclusive evidence could be obtained for it.

The other branch (ventral strand or placental strand) is very small and poorly developed. It traverses inward and enters the chalazal region. It may often consist of a few tracheids loosely placed one above the other (Text-Fig. 34) or oriented vertically or obliquely as in a number of species, *e.g.*, *P. pellucida*, *P. reflexa*, *P. fraseri*, *P. fenzlei*, *P. sandersii*, *P. sandersii* var. *argyreia* *P. sp.*$_1$, etc. It is significant to note that in some cases of *P. reflexa*, etc., the long axis of the tracheids of this branch lies at right angles to that of the ovule (Text-Fig. 34). In some cases their strand is well developed (Text-Fig. 35). It reaches the chalaza either almost straight (Text-Fig. 35) or it may pass for some distance towards the adaxial side and then negotiate a more or less sharp bend to reach the chalaza (Text-Figs. 29 and 36–38). Such a course of the ventral strand was observed in a number of species, *e.g.*, *P. cniapas*, *P. blanda*, *P. magnoliæfolia*, *P. peirescifolia*, *P. prostrata*, *P. incana*, *P. argyreia*, *P. sandersii* var. *argyreia*, *P. sp.*$_1$, *P. sp.*$_3$ and *P. sp.*$_4$. It is apparent that the ventral strand in these species is very rudimentary and it is used completely in supplying a single ovular trace, itself very insignificant.

The structure of the stigma in *Peperomia* deserves some detailed consideration. There is generally one fertile stigma on the abaxial side (Text-Figs. 28 and 29). It is densely staining and simply papillose



TEXT-FIGS. 16–30. Figs. 16 and 17. Serial cross-sections of a flowering node of *P. pellucida* showing method of branching. Fig. 18. Part of a young spike of *P. magnoliæfolia* cut in L.S. Note the horizontally running bundles in the cortex, each bifurcating to supply a flower and a bract. Fig. 19. L.S. of part of a spike of *P. magnoliæfolia.* Note a single bundle supplying two flowers. Figs. 20–22. Flowers cut in L.S. showing the course of vascular supply to the bract and flower. Fig. 20. *P. incana*; Fig. 21. *P. cniapas* and Fig. 22. *P. sandersii.* Fig. 23. *P. sandersii* var. *argyreia.* Note the descending and then ascending course of the bundle supplying the bract and flower. Fig. 24. *P. reflexa.* Note the supply to bract and flower separating just near the supply of the main axis. Fig. 25. *P. sandersii.* Note the

bract bundle passing downwards parallel to the surface of the axis. Fig. 26. *P. magnoliæfolia*. Note the axial tissue between the bract and flower. Fig. 27. Stamen of *P. pellucida* cut longitudinally showing vascular supply. Fig. 28. L.S. of flower of *P. pellucida* showing the course of vascular supply. Note the plate of vascular tissue below the receptive stigma. Fig. 29. L.S. of flower of *P. comarapana*. Note the bend in the ventral strand. Fig. 30. Plate of vascular tissue below the stigma from cross-section of a flower of *P. pellucida*.

A′, stele of main axis; *ax*, axial tissue; *b*, bend in the dorsal; *B′*, *C′* and *d′*, steles of branches; *br*, bract; *ch*, chalaza; *D*, dorsal; *fl*, flower; S_1, S_2. scales; *st*, stamen; *st′*, receptive stigma; *st″*, sterile stigma; *v*, ventral strand.

Figs. 16, 17, ×28; Figs. 18–20, 22, 24–26, ×36; Fig. 21, ×107; Figs. 23, 27, 30, ×161; Fig. 28, ×64; Fig. 29, ×24.

and is often conspicuous with finger-like projections (Text-Figs. 39 and 40). Two fertile stigmas were observed in some flowers of *P. reflexa*, *P. fraseri* and *P. comarapana* (Text-Fig. 41). In *P. pellucida*, *P. reflexa*, *P. metallica*, *P. rubella*, *P. sandersii*, *P. comarapana*, etc. the fertile stigma appears to be terminal or slightly lateral. But in some other species there is a protuberance on the adaxial side (sterile stigma) which develops into a prominent thumb-like structure as in *P. blanda* (Text-Fig. 40), *P. fenzlei* (Text-Fig. 42), *P. sp.*$_4$ (Text-Fig. 43) and *P. prostrata* or into a long tapering structure generally described as a beak as in *P. argyreia* (Text-Fig. 1), *P. incana* (Text-Fig. 20), *P. magnoliæfolia* (Text-Fig. 26) and *P. sp.*$_2$ (Text-Fig. 44). Out of the species studied the beak is longest in *P. magnoliæfolia*. Trelease and Yuncker (1950) report that the beak in this species may be as long as its fruit. In a few species this protuberance on the adaxial side is supplied with a bundle that is given off from the plate of vascular tissue lying below the stigma (Text-Figs. 45 and 46). This branch may stop at the base of the protuberance or may pass for some distance as in *P. prostrata*, *P. magnoliæfolia* (Text-Fig. 26) and *P. sp.*$_1$ (Text-Fig. 45), or it may go even almost up to its apex as in *P. argyreia* (Text-Fig. 1) and *P. sp.*$_2$ (Text-Fig. 44). This extension of vascular bundle into the protuberance (beak) appears to be of some significance and we shall return to it again in discussion.

During the course of this study some significant variations have been observed with regard to the number and course of the bundles within the ovary as well as with regard to the number of stigmas and ovules. It is considered worthwhile to describe them in some detail here.

A few flowers of *P. fraseri* were observed with two receptive stigmas and a bundle running on each side of the ovary wall. The vascular bundle that enters the base of the ovary splits up into two more or less equal branches (Text-Fig. 47). One of these passes as usual along the abaxial side while other runs along the adaxial side of the ovary (Text-Fig. 48). No definite bundle is seen supplying the chalaza except some procambial tissue which joins at the fork.

In another flower of *P. fraseri*, there were two ovules in the same ovary developing normally. The general vascular plan in this case was appreciably modified. After giving off the stamen traces the

TEXT-FIGS. 31–46. Figs. 31 and 32. Serial longitudinal sections of flower of *P. comarapana* showing two ventral bundles. Fig. 33. Note the well-developed dorsal bundle and ventral strand in *P. magnoliæfolia*. Fig. 34. Shows a few loose tracheids representing ventral strand in *P. reflexa*. Note the spirals of the tracheids. Figs. 35 and 36. Show the course of ventral strand in *P. incana*. Note the bend in its course in Fig. 36. Fig. 37. *P. cniapas*. Note the bend in the ovule and ventral strand.

Fig. 38. *P. cniapas* shows bend in the ventral strand. Fig. 39. Apex of the gynæceum of *P. reflexa* showing two receptive stigmas. Fig. 40. *P. blanda.* Note the prolongations of the epidermal cells of receptive stigma. Fig. 41. L.S. apex of young gynæceum of *P. comarapana* showing two receptive stigmas. Figs. 42–45. L.S. of flowers showing vascular supply. Note the vascular supply to the sterile stigma also in Figs. 44 and 45. Fig. 42. *P. fenzlei*; Fig. 43. *P. sp.*$_4$; Fig. 44. *P.sp.*$_2$; Fig. 45. *P. sp.*$_1$. Fig. 46. Shows the vascular supply to the sterile stigma in *P. magnoliæfolia.*

b, bend in the dorsal; D, dorsal; *ch*, chalaza; *st'*, receptive stigma; *st"*, sterile stigma; *v*, ventral strand; *v'*, tracheids arising from dorsal.

Figs. 31–32, 41, ×33; Fig. 33, ×240; Fig. 34, ×17; Figs. 35, 36, ×234; Figs. 37, 38, ×150; Fig. 39, ×135; Fig. 40, ×495; Figs. 42, 43, 46, ×51; Figs. 44, 45, ×27.

remaining floral supply splits up into three branches (Text-Figs. 49 and 50), two of which traverse antero-laterally (D_1 and D_2) and the third (D_3) posteriorly in the ovary wall. The antero-lateral branches at their bases gave off one trace each (V_1 and V_2) that supplied a corresponding ovule and then continued as D_1 and D_2 in the ovary wall (Text-Figs. 49–52). Just below the stigma all the three vascular bundles supplying the ovary wall fuse together to form a plate of tracheids (Text-Fig. 52). At the apex of the gynæceum there were two receptive stigmas (Text-Fig. 53).

Lobed ovules have been described earlier by Fisher (1914) in *Peperomia verticillata* etc., but the cases obserevd here in *P. reflexa*, *P. cniapas* and more frequently in *P. sp.*$_3$ appear to be somewhat different. They are remarkable in that they do not show any features of the ovules except for the fact that they develop from the base of the ovarian cavity. It is, therefore, doubtful whether the name lobed ovules is quite appropriate for these structures. They are just undifferentiated masses filling up the ovarian cavity (Text-Fig. 54).

Besides, these abnormal ovules show some variations in the course of the ventral strand which in all such cases does not stop at the chalaza but enters into the body of this structure. Generally this bundle is well developed and splits into two branches, each of which traverses up to the middle of the ovule (Text-Fig. 55) or even beyond (Text-Figs. 56 and 57) and may show further splitting in some cases (Text-Fig. 56). In one case where the ovule appears to be deeply lobed each of these two branches enters a lobe (Text-Fig. 57). Some of the ovaries showing such lobed ovules, have two receptive stigmas or one sterile and another receptive stigma.

One flower of *P. magnoliæfolia* showed two free ovaries each of which received a vascular bundle (Text-Figs. 58 and 59).

In another instance there were two ovules within a unilocular ovary of *P. peirescifolia* (Text-Fig. 60) but the vascular supply was of a typical gynæceum. The ovule towards abaxial side had a normal nucellus with a four-nucleate embryo-sac. The one towards the adaxial side was more or less conical and did not show any embryo-sac or even the integument.

TEXT-FIGS. 47–63. Figs. 47 and 48. Two sections from a series of longitudinal sections of abnormal flower of *P. fraseri* showing two carpellary dorsals. Figs. 49–53. Sections from an another series of longitudinal sections of abnormal flower of *P. fraseri* showing three capellary dorsals, two ventral strands and two ovules. Figs. 54–57. Show L.S. of abnormal flowers of *P. sp.*$_3$ showing abnormal development of ovule. Note the lobing of this tissue as well as the well-developed vascular supply within this region. Figs. 58 and 59. Two serial longitudinal sections of a flower of *P. magnoliæfolia* showing 2 ovaries in the axil of a bract. Fig. 60. L.S. flower of *P. peirescifolia* showing 2 ovules in the same locule. Note one of them is rudimentary. Figs. 61–63. Theoretical diagrams explaining the branching

of inflorescence. Fig. 61, *P. sandersii* var. *argyreia*. Figs. 62 and 63. *P. pellucida*. Branches that are modified into spikes are shown stippled and those that continued the vegetative growth are left blank.

A, main axis; *B*, *C*, *d*, branches; *ch*, chalaza; D, D_1, D_2. D_3, carpellary dorsals; *o*, ovary; *ov*, normally developing ovule; *ov'*, rudimentary ovule; S_1, S_2, S_3, S_4, scales; st_1 and st_2, stamens; *st'*, receptive stigma; *st"*, sterile stigma; V, V_1, V_2, ventral strands.

Figs. 47–53, ×105; Figs. 54, 58, 59, ×19; Figs. 55, 56, ×86; Figs. 57 and 60, ×36.

In contrast to the general condition when the ovule is erect and occupies the whole of space within the ovary there are many cases where the ovules are bent more or less towards the abaxial side, being attached to the adaxial side, and do not fill up the whole ovarian cavity, *e.g.*, *P. cniapas* (Text-Figs. 21, 37 and 38); *P. incana*, *P. sp.*$_3$ and *P. blanda*. The ovule in these cases appears to have a narrow base that looks like a stalk.

Conclusions and Discussion

Branching of the Inflorescence.—Out of the twenty species studied only *P. fraseri* and *P. sandersii* var. *argyreia* showed externally any signs of a branched inflorescence while in all others, spikes are typically solitary axillary or terminal with the exception of *P. pellucida* where they are also leaf opposed. The inflorescence in *P. fraseri* is typically racemose and in *P. sandersii* var. *argyreia* helicoid type of uniparous cyme though it is described as panicle or catkin (Bailey, 1949, 1950). Such a conclusion has an anatomical basis. It will be recalled that the main axis always ends in a spike and growth appears to be carried by the axillary bud of the first scale leaf which itself ends in a spike after producing a single scale leaf (second). The same is repeated further and consequently there are as many spikes as there are scale leaves at a node (Text-Fig. 61). Hence the inflorescence is of the cymose type and as the branches are always produced towards one side, *i.e.*, the first-scale-leaf side it can be described as helicoid type of uniparous cyme. This shows that the branches are condensed and after producing a single node they end in spikes. The course of the vascular bundles also supports this conclusion. A similar case has been recorded in *Piper umbellatum* (Nozeran, 1955).

Peperomia pellucida does not show externally such an elaborate branch system as does *P. sandersii* var. *argyreia* yet the flowering nodes are generally complex and condensed. It is very common to find more than one spike at each flowering node. One of them is opposite the leaf and the others are by its side which are sometimes borne on small 1–2-leaved branches. Anatomical studies have revealed the true relationship of these additional spikes. Obviously the leaf-opposed spike represents the main axis and the branching is sympodial (Text-Fig. 62). The additional buds by the side of the leaf base belong to the axillary branch and such a conclusion is supported from the position, the vascular connections, and the scale leaves (Text-Fig. 63). It appears

therefore to be a case of very much condensed helicoid cyme somewhat resembling *P. sandersii* var. *argyreia*.

The Flower.—Each flower arises in the axil of a bract whose morphological nature was suspected to be staminodal by Gunderson (1950). However, its mode of development and the course and behaviour of its vascular supply clearly reveal that it is a bract of the hypopeltate type.

The solitary bundle in the ovary wall that continues into the stigma is obviously the dorsal bundle of the carpel. In some abnormal cases of *P. fraseri* there may be two or three dorsal bundles. The other bundle which is generally very rudimentary is technically the fusion product of two ventral bundles of the carpel or the placental strand. This is used up completely in supplying a single ovular trace which too is very insignificant.

The Number of Carpels.—There has been some uncertainty about the number of carpels in the *Peperomia* gynæceum. Wettstein (1935), Rendle (1938), Trelease and Yuncker (1950) and Lawrence (1951) have not committed themselves on the subject. Van Tieghem (1891, 1918) definitely considered it as unicarpellate. Johnson (1914) too interpreted the gynæceum of *Peperomia hispidula* with a single bundle as unicarpellate and asserted that the developmental studies did not reveal the coalescence of three carpels. However, he is inclined to think that it is derived secondarily from a *Piper*-like gynæceum which has three to six vascular bundles and three carpels. Of these one is posterior median and the other two are anterio-lateral. Eckardt (1937) discussed at some length the probable number of carpels in *Peperomia*. He considered several suggestions that attempt to interpret *Peperomia* gynæceum in terms of *Piper* gynæceum which is essentially tricarpellary and also the one that envisages *Peperomia* gynæceum as having evolved quite independently from *Piper* type. But he does not appear to commit himself to either of the views.

In the absence of any direct evidence the problems can not be settled one way or the other with any certainty but circumstantial evidence leads me to believe that it can best be explained as pseudo-monomerous. Evidence for such a belief is obtained from the occasional occurrence of (1) more than one carpellary dorsal in the ovary wall and (2) more than one stigma. Let us test these possibilities one by one.

More than one carpellary dorsal has been observed during the present studies in some of the flowers of *P. fraseri*. In some cases observed, the gynæceum had two dorsal bundles, one on abaxial and the other on the adaxial side of the ovary wall. The ovule in such cases is supplied by some procambial tissue (representing ventral) arising from the place of bifurcation of the two carpellary dorsals. These flowers had two receptive stigmas.

In another instance a gynæceum of this species showed three dorsal bundles in the ovary wall one of which is adaxial and the other two

anterio-lateral. There are two ovules each of which is supplied by a vascular bundle that separates off from one of the carpellary dorsals. There are two receptive stigmas.

Leinfellner (1953, Plate IV, Fig. 4) gives a diagram of an additional bundle on the adaxial side running half way up in the ovary wall of *P. sandersii*. This is in addition to the one on the abaxial side. Though the author has not come across any such stage in his material of this species, it supports the observations in *P. fraseri*.

Thus a study of the vascular ground plan of the gynæceum reveals that it may consist of 2 or 3 carpels.

A detailed consideration of the stigma will also be useful in the same manner. Generally, the receptive stigma is lateral but in many species there appears by the side of the receptive stigma a finger-like prolongation on the posterior side. This finger-like prolongation varies in length in different species and it is much longer in *P. magnoliæfolia*. The nature of this prolongation has not been discussed satisfactorily by any of the previous workers. It is well developed in seven of the twenty species studied. The epidermal cells of this prolongation are barrel-shaped and turgid. Occasionally in some species like *P. fraseri*, *P. reflexa*, *P. comarapana* and *P. blanda*, this becomes partly or completely receptive and then resembles the receptive stigma in its structure. However, this sterile prolongation has been seen to receive supply from the dorsal in some species like *P. argyreia*, *P. sp.*$_2$, etc. These considerations do reveal that this structure may well actually be another (sterile or receptive) stigma. If this is true, then the natural corollary of this will be that the *Peperomia* gynæceum is bicarpellary although only one of the carpels is fertile and that it is not monomerous. In other words the *Peperomia* gynæceum can be regarded as pseudomonomerous and bicarpellary which may have had some connection in the past with the condition in *Piper* or *Pothomorphe*.

Placentation and Ovule.—The single erect ovule of *Peperomia* has sometimes in the past been interpreted as a direct continuation of the floral axis (Hanstein, 1870; Schmitz, 1875; Eichler, 1875; Sachs, 1882; Worsdell, 1904).

The axial nature of the basal ovules was questioned in *Typha* (Worsdell, 1904), Urticaceæ (Bechtel, 1921), Myricaceæ (Benson and Welsford, 1909), Polygonaceæ (Eber, 1934; Joshi, 1938); Juglandaceæ (Nast, 1935; Leroy, 1955), etc. In fact, Eames and MacDaniels (1947) conclude on the basis of anatomical evidence that no angiosperm ovule is cauline. The basal position is explained as derived from lateral position in *Typha*, from central in Polygonaceæ, parietal in *Juglans* and pendulous in Urticaceæ. More recently Puri (1952) has reviewed the work on placentation in angiosperms in great detail and it will be futile to cover that ground again here.

The mode of attachment of the ovule has been made a subject of special study in all the species of *Peperomia* investigated here. As has already been recorded (Murty, 1952) some anatomical evidence

has been brought together which indicates that the present-day basal position of the ovule in *Peperomia* is derived from an originally lateral position. It will be worth while to consider the evidence in some detail.

It may be recalled that in *Peperomia* the rudimentary ovular trace is supplied by an equally rudimentary ventral strand (Placental strand) which itself appears to become converted into the former. The course of this bundle is considered to be of special consequence in determining the nature of placentation in *Peperomia*. In some species, *e.g.*, *P. cniapas*, *P. comarapana*, *P. blanda*, *P. magnoliæfolia*, *P. prostrata*, *P. peiresci-folia*, *P. blanda*, *P. incana*, *P. sandersii* var. *argyreia*, *P. argyreia*, *P. sp.*$_1$, *P. sp.*$_3$ and *P. sp.*$_4$, it generally negotiates a more or less sharp bend before it transforms itself into the ovular trace. This bend is especially prominent in *P. comarapana* and *P. incana* where the bundle is comparatively well developed. In some species like *P. reflexa* where there is no bend in this bundle the orientation of spirals in the tracheids of this bundle reveals a further reduction from such a condition. These peculiarities of the ventral strand are considered here as an important structural feature in so far as they foil any attempt to interpret the ovule in *Peperomia* as an axial structure. Rather they tempt one to visualize an ancestral condition where there might have been several ovules arranged laterally and supplied by one well developed placental strand. In course of evolution most of the ovules got lost and only one, the lowest one, survived. This might have shifted further down into the base of the ovary resulting in the present-day condition. This is, no doubt, pure and simple imagination. But it must be pointed out that there is some justification for this in the course of the ventral strand. Otherwise how else can it be explained.

Similar bendings in the course of the vascular bundles have also been reported in *Bœhmeria cylindrica* (Bechtel, 1921) and *Myrica* (Benson and Welsford, 1909), *Juglans* (Benson and Welsford, 1909; Leroy, 1955), etc., and they have been interpreted in the same way.

Thus it is clear that the basal ovule in *Peperomia* is only apparently basal. It appears to have been derived from a lateral position. The use of the term basal placentation for such a condition is, therefore, somewhat misleading. As suggested earlier (Murty, 1952) the condition can be better described as sub-basal (Baillon, 1874; Puri, 1952).

Summary

Anatomical studies recorded here have revealed that the inflorescence in *P. sandersii* var. *argyreia* and *P. pellucida* is uniparous cyme. The presence of leaf-opposed spikes and even more than one spike at a node in many cases of *P. pellucida* was explained as due to the condensed cymose type of branching. Minute scale leaves hitherto not described have been recorded and their presence have been utilized in elucidating the structure of the node.

The floral anatomy of twenty species of *Peperomia* has been described in detail and the course of vascular bundles has been taken into account in interpreting the nature of the sterile stigma, the number of carpels and placentation.

The ventral strand, which in some species itself appears to enter the chalaza only after negotiating a bend and the orientation of spirals in its tracheids, has been taken advantage of in interpreting the ovule to be only sub-basal and derived from a lateral position.

Similarly, the presence of sterile protuberance at the top of the ovary on the adaxial side and the presence of vascular bundle as well as the occasional presence of a second receptive stigma led to the conclusion that the sterile lobe represents a second stigma.

The occasional presence of more than one dorsal bundle, sterile or receptive stigma in addition to the normal one have been taken into account in interpreting the ovary as pseudomonomerous and bicarpellary, derived from a tricarpellary condition.

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A FOSSIL DICOTYLEDONOUS WOOD FROM THE DECCAN INTERTRAPPEAN BEDS OF MAHURZARI

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Introduction

The fossil piece of wood No. B3B/C collected by Dr. Chitaley from Mahurzari was kindly placed at my disposal for studying its anatomical characters.

In India very few fossil dicotyledonous woods have been worked out so far. From Tertiary beds a few fossil woods have been investigated by Chowdhury (1936), (1938), Chowdhury and Ghosh (1946), Chowdhury and Tandon (1949), Navale (1955) and Ramanujam (1953, 1954 *a*, 1954 *b*, 1955, 1956).

From Deccan Intertrappean beds of Mohgaon-Kalan only one dicotyledonous wood was described in detail by Rode (1936). Verma (1950) published a short note about another dicot wood from the Deccan Intertrappean Series which he had described as showing resemblances with *Sonneratia*.

In the collections made so far from various Intertrappean beds there is a great predominance of petrified pieces of dicotyledonous woods.

The fossil piece under investigation was 2·5″ long and 2·5″ thick. It had variegated colour ranging from yellow to light brown, with a few dark patches here and there. The fossil was a silicified piece of dicotyledonous secondary wood. It appeared to be a portion far away from the central pith of a trunk of a big tree.

Transverse, tangential and radial sections were cut. From the study of these sections it was seen that the wood had got badly pressed in preservation.

Peel sections were also tried after etching the surface with HF without any success. A few pieces of the wood were macerated with HF to liberate the fibres: Very few fibres could be recovered.

Horizon and age of the locality.—The village Mahurzari in Nagpur District is about 8 miles from Nagpur proper, and it lies on lat. 21° 13′, long. 79° 05′. Deccan Intertrappean beds are exposed at this place and pieces of petrified dicotyledonous and monocotyledonous woods are

seen strewn all over the fields near the fossiliferous rocks, where some of the fossils are still seen *in situ*.

The age of the Deccan Intertrappean Series was reported to be Tertiary by Sahni (1940).

Diagnosis

Decorticated secondary wood; wood diffusely porous, pores mostly solitary to multiples of 2's or 3's—pores small to medium size; tyloses absent; gummy deposits absent; intervessel pits with hexagonal borders. Wood parenchyma sparse. Medullary rays 1 to 4 seriate, length being 8 to 32 cells; slightly heterogeneous, showing the presence of intercellular spaces. Fibres arranged in radial rows in transverse section, angled, not very heavily thickened, showing simple pits on radial walls. Ripple marks absent.

Description

Macroscopic structure

The fossil is a diffusely porous wood.

Growth rings are not seen macroscopically.

Vessels are visible to the naked eye, and distinct with hand-lens.

Fibres are collectively visible on polished surface of the piece. They are better preserved than other tissues.

Parenchyma is sparse and not visible to the naked eye.

Rays are visible to the naked eye as whitish lines.

Ripple marks are absent.

Microscopic structure

Growth rings are seen indistinctly associated with thickened fibres (Pl. XXIV, Figs. 1 and 2).

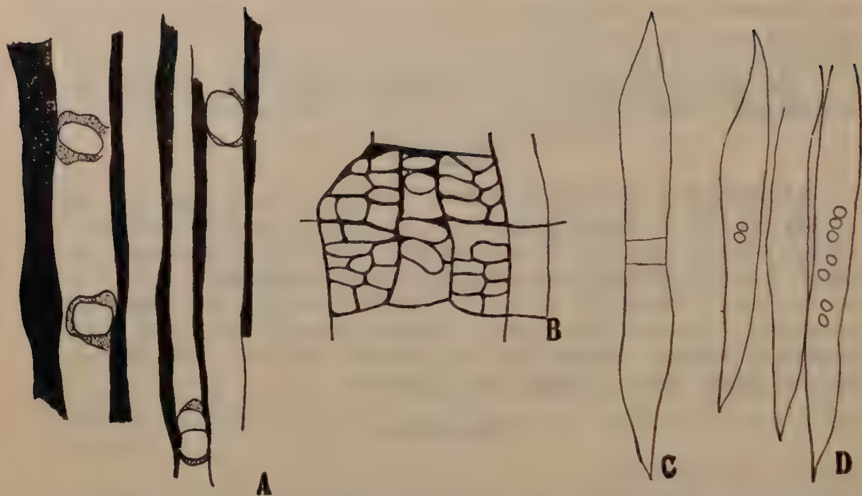
Vessels are evenly distributed at particular areas, 5 to 6 per sq. mm. They are mostly single and rarely found in radial rows of 2's or 3's (Text-Fig. 1, A; Pl. XXIV, Figs. 1 and 2). The vessel wall is not very thickened. Tyloses are absent. In cross-section the vessels are seen oval, at times being round, medium size, the diameter varying from 100 to 200 μ. Vessel segment is short, its length being 255 μ and truncate at both ends. Perforation plate is simple, horizontal to slightly oblique. Intervessel pits have narrow hexagonal borders. They are closely crowded together (Pl. XXIV, Fig. 4).

Vessel ray pits are simple and attain a large size (Text-Fig. 1, B; Pl. XXIV, Fig. 3).

Parenchyma is sparse, and paratracheal (Text-Fig. 1, A).

It forms a single sheath round the pore.

Vessel-parenchyma pits not well seen because of bad preservation.



TEXT-FIG. 1. A. Semi-diagrammatic cross-section showing the distribution of parenchyma, ×40. B. Vessel ray pitting, ×300. C. A single septate fibre, ×200. D. Fibres showing simple pits on radial walls, ×165.

Rays.—In tangential section the medullary rays are very obliquely pressed. Only a few short medullary rays are drawn (Text-Fig. 2, A, B, C, D), while the long rays are well seen (Pl. XXIV. Fig. 6). From the study of these rays it is seen that they are slightly heterogeneous (Pl. XXIV, Fig. 5), a few marginal cells being erect. Width varies from 2 to 4 cells and length varies from 8 to 32 cells. Intercellular spaces b tween the ay cells are well seen (Text-Fig. 2, A, B, C, D).

Fibres.—In cross-section the fibres are angular, arranged in regular radial rows between medullary rays (Pl. XXIV, Figs. 1 and 2). Average diameter of the fibre cell is 44 μ. Thickness of the fibre wall varies from 2 to 3 μ. Inter-fibre pits are seen at places on radial walls. They are simple (Text-Fig. 1, D).

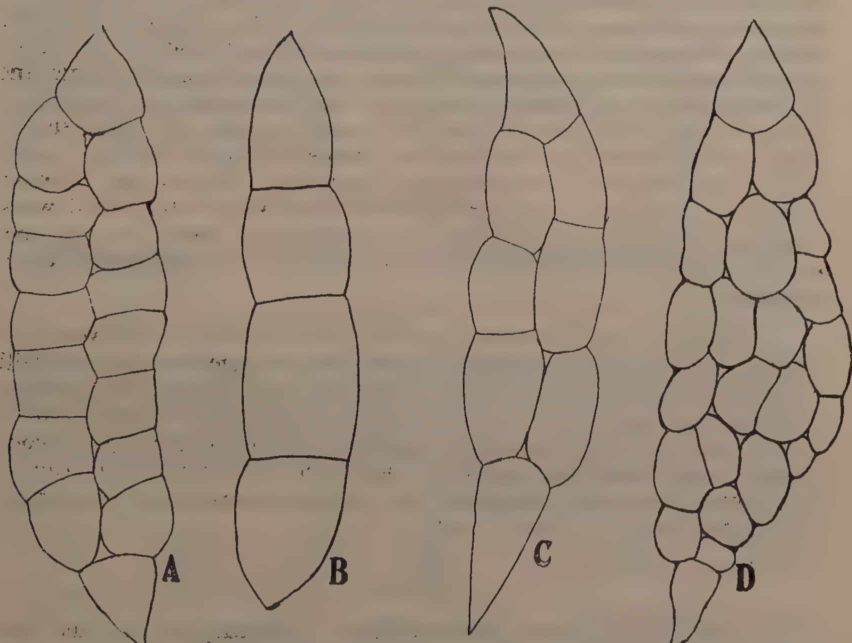
Indentification

From the anatomical details of the present wood, it is evident that the following characters which are shown by this wood might be used with advantage in an attempt to identify this wood to the family it may belong.

1. Wood diffusely porous.
2. Vessels usually solitary, at places found in radial rows of 2's or 3's. Perforation plate exclusively simple.
3. Parenchyma sparse, paratracheal.
4. Medullary rays multiseriate, uniseriates few. Multiseriate rays 2 to 4 seriate, slightly heterogeneous,

5. Fibres in radial rows between the medullary rays, septate, simple pits on radial walls.
6. Ripple marks absent.

Among the structural features of the fossil there is none which could be, if considered alone, striking enough to help in its identification. I, therefore, have adopted the well-known method of determining the affinities by taking combination of anatomical characters and going through all the dicotyledonous families for comparison. It will be seen that the following families alone show considerable resemblance: Leguminosæ, Datiscaceæ, Anacardiaceæ and Burseraceæ.



TEXT-FIG. 2. A. Biseriate medullary ray showing clearly the intercellular spaces, ×255. B. Uniseriate medullary ray, ×450. C. Biseriate medullary ray with long tip cells, ×450. D. Tetraseriate medullary ray showing clearly the intercellular spaces, ×300.

Leguminosæ.—The woods of Leguminosæ agree with the fossil wood in a number of features, but differ very much in presence of greatly developed parenchyma.

Datiscaceæ.—There are two tree genera in this family, *Octameles* and *Tetrameles*. Both these genera agree with the fossil wood in general anatomical features of vessels and parenchyma. The difference lies greatly in its medullary rays.

Anacardiaceæ.—Genera *Buchanania* and *Odina* comes close to the fossil wood under consideration in a number of characters, but

Buchanania differs from it in the presence of vasicentric septate fibres mixed up with parenchyma, and presence of non-septate fibres in the ground tissue (Metcalfe and Chalk. 1950). Also intercellular canals present in the rays of almost all species of *Buchanania*, are absent in the fossil wood under consideration.

Genus *Odina* as a matter of fact shows more similarities than genus *Buchanania*. Still it differs from the fossil wood in the presence of intercellular canals in the rays of almost all species of *Odina*.

Burseraceæ.—Genera *Bursera*, *Boswellia*, *Garuga* and *Pachylobus* show several features common to the fossil wood. The woods of Burseraceæ display a high degree of uniformity in the structure (Heimsch, 1942). All species of the above genera are diffuse porous, vessels thin-walled pores solitary and also multiple, vessel perforation simple and intervessel pitting alternate, vessel ray and vessel parenchyma pitting small to large, round or irregular to oblong or gash-like, most species show heterogeneous rays seldom more than 4 cells wide and low. Intercellular canals occur occasionally in the rays. Fibres are septate. The abovementioned characters are well met with in the fossil wood under consideration except for the intercellular canals in the rays. But as said above intercellular canals in the rays of Burseraceæ occur occasionally.

The fossil wood shows a greater resemblance to the woods of Anacardiaceæ and Burseraceæ. It has been suggested by (Metcalfe and Chalk. 1950), that intercellular canals in the woods of Anacardiaceæ is a constant feature in almost all species of the different genera, while in Burseraceæ it is of sporadic occurrence. The present fossil wood under consideration does not show the presence of intercellular canals. Thus from the above it is very likely that the fossil wood belongs to Burseraceæ than to Anacardiaceæ.

Summary

A fossil decorticated dicotyledonous secondary wood has been described for the first time from the Deccan Intertrappean beds of Mahurzari in Nagpur District. From the anatomical study of the wood the following few characters are found to be important for its identification:—

1. Vessels mostly solitary, placed at great distance from one another and diffusely arranged.
2. Parenchyma sparse and paratracheal.
3. Intervessel pitting hexagonal and closely crowded together.
4. Medullary rays multiseriate and heterogeneous; medullary ray cells large.
5. Fibres thin-walled and septate with simple pits on radial walls.

Comparisons with living members of the families Datiscaceæ, Anacardiaceæ and Burseraceæ (Metcalfe and Chalk, 1950; Pearson and Brown, 1932; Heimsch, 1942 and Gamble, 1902) are made since these families show much resemblance to the present wood. It has been found that the woods of Burseraceæ show more characteristics common to the fossil wood.

Acknowledgements

The author is extremly indebted to Dr. (Mrs.) Chitaley of Government College of Science, under whose kind guidance and encouragement this work was carried out. She is grateful to Dr. K. A. Chowdhury for helpful suggestions, to Prof. Dutt for making available to her the living material of *Tetrameles nudiflora* and also to the Forest Department of Nagpur for the supply of living material of Burseraceæ woods. She is highly grateful to the Government of India, for the award of a Senior Research Scholarship.

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EXPLANATION OF PLATE XXIV

FIG. 1. T.S. wood to show distribution of vessels and fibres, ×23.

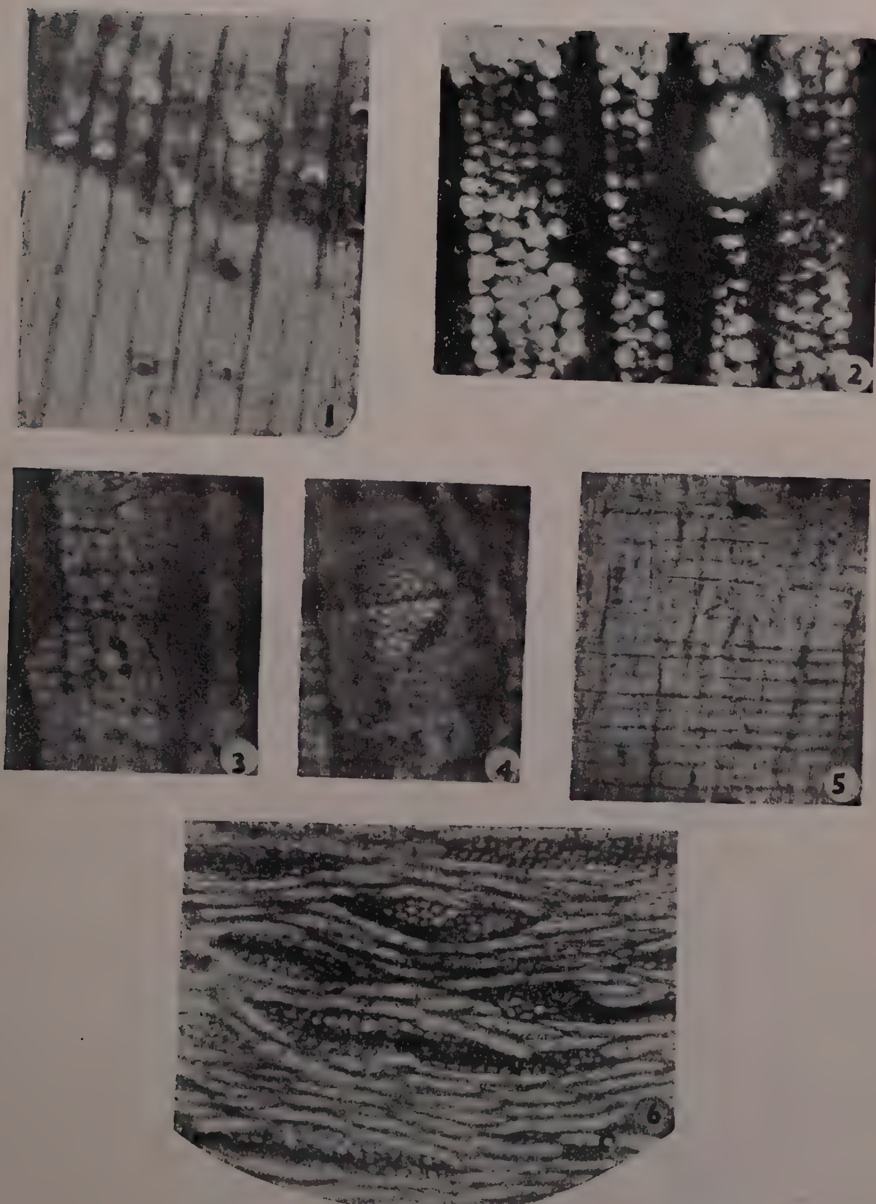
FIG. 2. T.S. wood showing thickened fibres at places, ×83.

FIG. 3. Vessel ray pitting, ×148.

FIG. 4. Intervessel pitting, ×152.

FIG. 5. Radial section showing slightly heterogeneous condition of the medullary rays, ×200.

FIG. 6. Tangential section of the wood showing the medullary rays, ×27.



L. J. Shallom

FIGS. 1–6

NOTES ON FUNGI FROM NORTH-EAST INDIA

II. An Undescribed Myxomycete from Assam

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During the routine examination of diseased specimens of tea and ancillary crops in the field as well as in the laboratory, the author and his collaborators had the opportunity of collecting many species of myxomycetes either on dead bark, roots or leaves.

Upto now forty-two species have been recorded on various substrata, but the identity of some of the collected specimens could not be established conclusively. It is intended to publish a detailed account of the myxomycetes occurring in the tea gardens of North-east India, elsewhere in course of time. It is certain, apparently, that almost all the species of myxomycetes collected are purely saprophytic and in no way incite pathologic symptoms on the plants on which they are found.

This brief paper describes a new species of *Arcyria*, one of the members of Trichiaceæ (*sensu* Martin, 1949). A set of four collections has been made, three of which were on decaying bark of tea bush infected by either *Fomes lamaœnsis* (Murr.) Sacc. and Trott. or *Ustulina deusta* (Fr.) Petrak. One collection has been made on some unidentified bark. The following description is based on a critical examination of all the collections.

Only in one instance was the plasmodium of the myxomycete observed. It was pale dirty white in colour, becoming slightly brownish when incubated in a moist chamber. Sporangia were produced readily in the laboratory from the plasmodium. They are cylindrical, straight or slightly undulate, densely aggregated on the substratum and form continuous groups up to 4 cm. in diameter, measuring up to 4 mm. in height (mostly 2 mm.) and 0·75 mm. in diameter. The sporangia are distinctly stipitate, with the apex which is more often truncate than obtuse. The mature sporangia become expanded twice to five times their original height and the capillitium presents a pendant appearance. Peridium thin, smooth, evanescent; stalk well developed, up to 500 μ long and 50 μ in diameter at the base. Stipe is usually smooth, very rarely longitudinally plicate with a distinct, thin, membranous hypothallus which is deep brown in colour. The hypothallus may be discrete or continuous, in the latter case a group of 4–5 sporangia are

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seen to arise from the same point. The sporangia are Salmon (10 A 7),† Musk melon (11 A 8) or Paloma (12 A 9) in colour, turning Sandalwood (14 A 7) or Tanbark (14 B 8) or Leather Brown+ (14 A 10) on weathering. The stipe is concolorous with the sporangium and ends in a funnel-shaped calyculus, which is up to 200 μ in diameter at the widest part, smooth or indistinctly plicate. Calyculus and the stipe are closely packed with spore-like cells which are spherical toward the calyculus and rather polygonal toward the hypothallus. Capillitium well developed, greatly elastic, consisting of a complex network of ornamented threads appearing Tansan + (12 B 6) or Polo tan (13 C 6) in colour, measuring up to 3 μ in diameter excluding the ornamentations, mostly attached in the middle with a few peripheral attachments on the calyculus. The capillitium separates readily from the cup. The threads are marked with blunt cogs and incomplete ring-like thickenings forming an irregular open spiral. Only in two instances the free ends of the capillitium could be discerned. Spores are formed abundantly, brownish *en masse*, pale yellowish individually, spherical to globose or subspherical, distinctly smooth-walled, measuring up to 6 μ, mostly 4·0 μ in diameter.

This myxomycete is unmistakably an *Arcyria* belonging to the family Trichiaceæ of the order Trichiales under the subclass, Myxogastres of Myxomycetes (*sensu* Martin, 1949). In attemping to fix the identity of this myxomycete, it was compared with *Arcyria œrstedtii* Rost., *A. nutans* (Bull.) Grev., *A. stipata* Lister, and *A. incarnata* (Pers.) Pers. The specimen in question differs from *A. œrstedtii* in the absence of persistent shield-like peridial fragments. *A. œrstedtii*, besides is crimson in colour with a capillitium which is 3 to 5 μ in diameter, with numerous bulbous enlargements and conspicuous spines that are somewhat longer measuring up to 3 μ in length. It resembles *A. œrstedtii* and *A. nutans* in the pendant or drooping capillitium at maturity but differs sharply from the later in the absence of a spinulose reticulated calyculus and sharp spiny capillitium with short lines of broken reticulation. It agrees with *A. stipata* Lister *sensu* Lister (1925) in the capillitial dimensions but not in the ornamentations. *A. stipata* has capillitium with broad-based spines or transverse ridges with 3 to 4 spiral bands and is not infrequently marked with minute spinules in addition. It may be mentioned here that *A. stipata* is treated as a synonym of *Hemiarcyria stipata* (Schw.) Macbride by Martin (*op. cit.*). The only species of *Arcyria* which is nearest to the present collection is *A. incarnata* (Pers.) Pers. Our collection agrees well with this species in general appearance but could be differentiated from it in the Salmon-coloured, densely aggregated sporangia which become characteristically pendant at maturity. Besides, the sporangia are distinctly stipitate, with the capillitium which is highly elastic, becoming expanded from 2 to 5 times the original height. Capillitial threads are much thinner measuring up to 3 μ in diameter as compared to *A. incarnata* where they are

† The numerical designations corresponding to different colours in Maerz and Paul's *A Dictionary of Color*, McGraw-Hill, New York (1930) are included in parenthesis.

up to 5 μ. Moreover, the capillitium has very few free ends, and the spores are much smaller measuring up to 6 μ (mostly 4 μ) in diameter. Hence a new species, namely, *Arcyria assamica* is proposed to accommodate our collection.

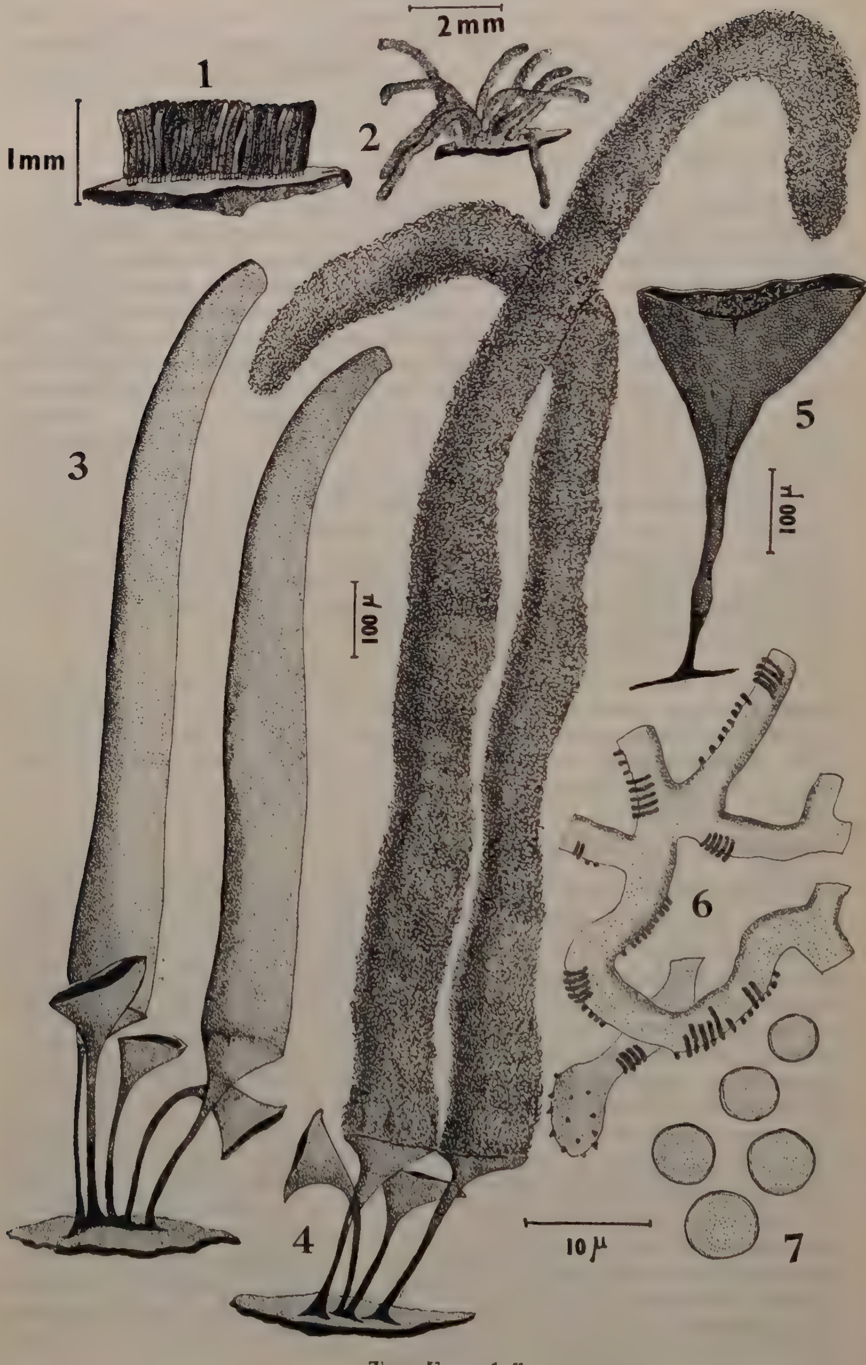
Arcyria assamica Agnihothrudu sp. nov.

Plasmodium pallide sordido-brunneum vel aqueum colore; sporangia dense aggregata, cylindrica vel subcylindrica, apice obtuso vel sæpius truncato, 1 to 4 mm. alta, 0·25 to 0·75 diam., distincte stipitata, ad maturitatem multum expansa, magnitud. usque ad 8 mm. longa, visu demissa, salmonea, marcescentia evadentia corio-brunnea; peridium evanescens, fere leve; stipes ut plurimum brevis, 200 to 500 ×20 to 50 μ, levis vel indistincte plicatis, hypothallo ornatus discreto vel continuo; calyculus latus, 100 to 200 μ diam. ad partem latiorem; stipes et calyculus referti cellulis sphæricis similibus sporis, sporangio concolores. Capillitium laxum, valde elasticum, sese expandens bis vel quinquies vel pluries præter altitudinem sporangii, constans e reticulo denso filamentorum bubalinorum diamentientium 1·5 to 3·0 μ, ut plurimum fixum ad medium calyculi, notatum annulis incompletis et dentibus efformantibus inflexionem spiralem apertam faciliter separabilem a calyculo. Sporæ brunneæ in massa, pallide luteo-brunnea vel incolores fere in luci transmissa sphæricæ vel subsphericæ, levibus parietibus præditæ, magnit. 3·5 to 6·0 μ in diam.

Typus lectus in cortice evanescente *Camellia sinensis* (L.) O. Kuntze simul cum *Ustulina zonata* (Lev.) Sacc. [= *U. deusta* (Fr.) Petrak] in campo stationis experimentalis Tocklai, ad Cinnamara, in Assamia a V. Agnihothrudu die 17 aprilis anni 1957 et positus herbario mycologico eiusdem stationis, sub numero 87.

Arcyria assamica Agnihothrudu sp. nov.

Plasmodium pale dirty brown to watery in colour; sporangia densely aggregated, cylindric to subcylindric with an obtuse or more often a truncated apex, 1 to 4 mm. in height, 0·25 to 0·75 mm. in diam., distinctly stipitate, becoming greatly expanded with maturity, measuring up to 8 mm. in length and presenting a drooping appearance, salmon-coloured, turning leather brown on weathering; peridium evanescent, almost smooth, stalk usually short, distinct, 200 to 500 μ by 20 to 50 μ smooth or indistinctly plicate, with a hypothallus which is discrete or continuous; calyculus broad, 100 to 200 μ in diam. at the widest part; stipe and calyculus filled with spherical spore-like cells, concolorous with the sporangium. Capillitium loose, very elastic, expanding to 2 to 5 times or more the height of the sporangium, consisting of a dense reticulum of pale brown threads, 1·5 to 3 μ in diam., attached mostly in the middle of the calyculus. marked with incomplete rings and cogs forming an irregular open spiral easily separating away from the calyculus; spores brownish in mass, pale yellowish-brown to almost colourless in transmitted light, spherical to subspherical, smooth-walled, measuring 3·5 to 6 μ (mostly, 4 μ) in diam.



TEXT-FIGS. 1-7.

TEXT-FIGS. 1–7. *Arcyria assamica* Agnihothrudu. Fig. 1. Sporangial aggregate on a piece of stem bark of tea. Young sporangia are with the peridium intact. Fig. 2. Sporangia without the peridium, showing the pendant nature of the capillitial threads. Fig. 3. Young sporangia and calyculi. Fig. 4. Mature sporangia. Fig. 5. Enlarged calyculus and stipe showing hypothallus and spore-like contents. Fig. 6. Capillitium showing the free end. Fig. 7. Spores. All figures drawn from M.H.T.E.S. No. 87.

Type collected on decaying bark of tea bush *Camellia sinensis* (L.) O. Kuntze infected by *Ustulina zonata* (Lev.) Sacc. [= *U. deusta* (Fr.) Petrak] in Tocklai Experimental Station campus, Cinnamara, Assam, collected by V. Agnihothrudu, 17–4–1957, deposited in the Mycological Herbarium, Tocklai Experimental Station No. 87. On unidentified bark. Coll. Mr. H. K. Phukan, Jorhat, 12–8–1957, M.H.T.E.S. No. 88. On tea bush attacked by *Fomes lamaœnsis* (Murr.) Sacc. and Trott., Tyroon tea estate, Coll. V. Agnihothrudu and K. C. Sarmah, 21–11–1957, M.H.T.E.S. No. 89. On tea bush infected by *U. zonata*, Nagadhoolie tea estate, coll. V. Agnihothrudu and K. C. Sarmah, 3–6–1957, M.H.T.E.S. No. 90.

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THE FEMALE GAMETOPHYTE OF *ACALYPHA MALABARICA* MUELL. WITH A BRIEF DISCUSSION ON THE PENÆA TYPE OF EMBRYO-SAC

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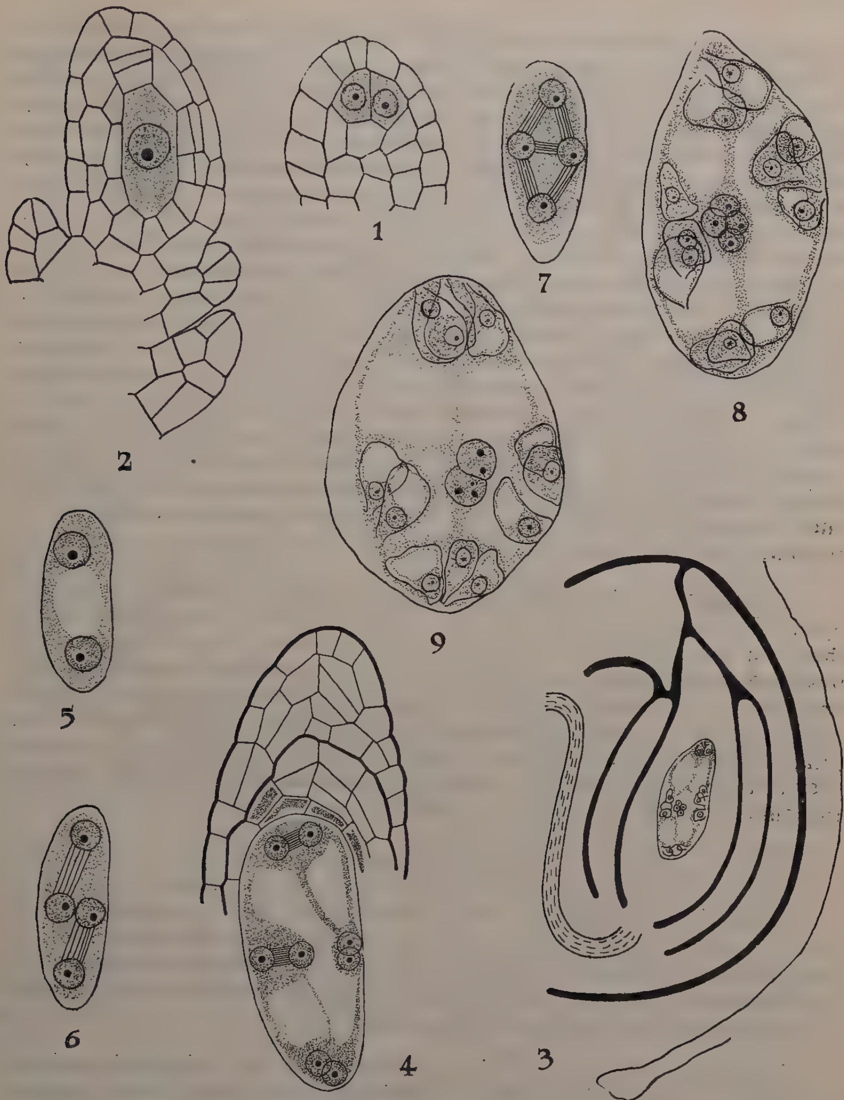
INTRODUCTION

IN 1909 Stephens described the Penæa type of embryo-sac in three genera of the Penæaceæ. This type is now reported for several families of Angiosperms particularly the Malphigiaceæ and Euphorbiaceæ (Maheshwari, 1950). In *Acalypha*, a member of Euphorbiaceæ, the Penæa type of embryo-sac is recorded in *A. australis* (Tateishi, 1927), *A. tricolor* (Swamy and Balakrishnan. 1946), *A. rhomboidea* (Landes, 1946) and *Acalypha* spp. (Arnoldi, 1912). In addition, this genus also exhibits two other types of embryo-sacs. Peperomia hispidula type occurs in *A. lanceolata* (Thathachar, 1952). A modified Penæa type is met with in *A. indica* (Maheshwari and Johri, 1940, 1941), *A. fallax* (Banerji, 1949) and *A. ciliata* (Kajale and Murthy, 1954). The present paper deals with the ovule and embryo-sac of *Acalypha malabarica* Muell., a species which grows abundantly round about Nagpur.

OBSERVATIONS

The gynæcium in *Acalypha malabarica* is tricarpellary and trilocular. Each loculus contains a crassinucellate, anatropous and bitegmic ovule pendulous from the upper end of the axile placentation. The integuments appear almost simultaneously (Text-Fig. 2) but soon the outer overgrows the inner and envelops it. The outer integument which forms the micropyle (Text-Fig. 3) points upwards as in *A. ciliata* (Kajale and Murthy, 1954). The obturator arises from the placenta above the funiculus and as it develops it meets the projecting nucellar beak while a part of it enters the exostome on the funicular side. It is composed of compact cells unlike in *A. ciliata* (Kajale and Murthy, 1954) and species of *Euphorbia* (see Kajale and Rao, 1943) where it consists of loosely arranged elongated cells. The nucellar epidermis divides periclinally and anticlinally to form the nucellar beak, whose basal portion consists of a few layers of the parietal tissue (Text-Fig. 4).

The hypodermal archesporium consists of a single cell though sometimes 2 or 3 cells are present (Text-Fig. 1). A multicellular archesporium is reported for several species of *Acalypha* (see Kajale and Murthy, 1954). The archesporium divides forming a primary parietal



TEXT-FIGS. 1–9. *Acalypha malabarica.* Fig. 1. L.S. nucellar apex showing two archesporial cells. Fig. 2. Same as above showing a megaspore mother cell. Fig. 3. L.S. ovule at mature embryo-sac stage; note obturator entering the micropyle formed by outer integument. Fig. 4. L.S. apex of ovule showing nucellar beak formed by epidermis and parietal tissue. Fig. 5. Bi-nucleate embryo-sac. Figs. 6 and 7. Embryo-sac showing crosswise arrangement of 4 nuclei. Fig. 8. Mature embryo-sac showing 4 groups of egg apparatus and 4 polars. The egg in the micropylar quartet is not shown. Fig. 9. Mature embryo-sac showing formation of secondary nucleus. Figs. 1 and 2, × 900. Figs. 3 and 4, × 275. Figs. 5–9, × 900.

cell and a megaspore mother cell. The primary parietal cell by further divisions forms a parietal tissue. The megaspore mother cell increases in size, its nucleus divides and no wall is formed. The daughter nuclei occupy the poles of the embryo-sac separated by a vacuole (Text-Fig. 5). The two nuclei divide in such a manner so as to cause the resulting four nuclei to become arranged in a crosswise manner as in other species of *Acalypha* (Text-Figs. 6 and 7). All these nuclei are connected by secondary spindle fibres. No wall appears between them and the central vacuole disappears. The four megaspore nuclei divide twice forming 16 nuclei arranged in four quartets. Of these, two quartets occupy the two poles of the embryo-sac while the remaining two are situated laterally. Three nuclei in each quartet form the egg apparatus consisting of two synergids and an egg essentially as in other species of *Acalypha* (Text-Fig. 8). The fourth nucleus from each quartet migrates to the centre. These unclei fuse with each other either simultaneously or in pairs (sometimes three may fuse together) to form a single tetraploid nucleus (Text-Fig. 9). Sometimes 5 or 6 nuclei fuse to form a pentaploid or hexaploid nucleus. These additional nuclei are obtained from one or both the lateral quartets which consequently consist of an egg and synergid only (Text-Fig. 9).

The egg apparatus at the micropylar end points towards the micropyle. The one at the chalazal end points towards the chalaza while those on the lateral sides usually point outwards. Several cases were observed where the egg and synergids showed departure from the normal orientation. Occurrence of lateral egg apparatuses near the chalazal quartet as in *A. tricolor* (Swamy and Balakrishnan, 1946) and *A. ciliata* (Kajale and Murthy, 1954) was occasionally noticed (Fig. 9). In certain preparations the cells of the lateral or chalazal quartet did not acquire the characteristics of egg or synergids.

Discussion

Crosswise arrangement of the megaspore nuclei appears to be quite typical of the genus *Acalypha*. Such an arrangement can be derived from the linear pattern if the necessary space becomes available, by the lateral enlargement of the embryo-sac, for the oblique and parallel orientation of the spindles during meiosis II.

Each one of the four nuclei thus arranged divides twice and produces quartets in four distinct groups forming a 16-nucleate embryo-sac of the Penæa type. This type appears to be an ancestral pattern for the genus *Acalypha* and the other two types in this genus represent a derived state.

According to the view put forward by Schnarf (1936) the monosporic 8-nucleate embryo-sac is most primitive because: (1) it is widely distributed in Angiosperms, (2) the female gametophyte of the Pteridophytes and Gymnosperms is monosporic, and (3) the other types of embryo-sacs can be easily drived from it. In my opinion it is further characterized by two more important features. In the first place

the nuclei show distinct tendency to organize into quartets. Secondly one of the nuclei in each quartet is let off for polar fusion. Though the number of quartets and polars is higher in *Acalypha* than in the monosporic embryo-sacs, these two essential features are shared by the Penæa type also and therefore, it should be regarded as the most primitive for the genus *Acalypha*. Besides, the other two types of the embryo-sacs reported in the genus can be easily derived from the Penæa type.

The trend of specialization in this genus is towards reduction in the number of cells in each quartet and to release progressively greater number of nuclei for polar fusion. The series begins with *A. malabarica* where 4 nuclei take part in polar fusion and 12-nuclei—3 in each group—form cells. Next stage is represented by some ovules of this very species where 5 or 6 nuclei in the embryo-sac fuse together and 11 or 10 nuclei organize into cells. These additional polars are drawn from one or two lateral groups which now consist of 2 cells. Some ovules of *A. indica* constitute a further stage in the series. Here 7 nuclei fuse in the centre of the embryo-sac, and now 3 groups—two lateral and one chalazal—consist of 2 cells (Maheshwari, 1950). The next stage in the series is represented by the normal condition in *A. indica* in which 8 nuclei fuse as polars and all the four groups consist of 2 cells (Maheshwari, 1950). It is significant to note that the micropylar group is affected last.

The series between *A. indica* and Peperomia hispidula type met with in *A. lanceolata* (Thathachar, 1952), is not so complete. The latter has 14 free nuclei taking part in polar fusion and there are 2 cells at the micropylar end to represent egg and synergid. However, cases were recorded in *A. indica* (Maheshwari, 1950) and *A. ciliata* (Kajale and Murthy, 1954) where 10 nuclei were free for polar fusion. The higher number, *viz.*, 11, 12 and 13 to serve as polars is not so far recorded in any species of *Acalypha*. A detailed investigation of other species of this genus, therefore, should prove interesting from this point of view.

The embryo-sac of *A. lanceolata* (Thathachar, 1952) which conforms to the *P. hispidula* type should at present represent the climax of the series till future research reveals an embryo-sac with one egg and 15 polars.

SUMMARY

The ovule is pendulous, crassinucellate, bitegmic and anatropous. The outer integument forms the micropyle. The nucellar beak is developed by the nucellar epidermis and the parietal tissue. The obturator is compact. The hypodermal archesporium usually consists of one and sometimes 2 or 3 cells. The embryo-sac conforms to the Penæa type. It is concluded that the Penæa type represents the ancestral pattern for the genus *Acalypha* and other types are derived from it by reducing the number of cells in each quartet and releasing more free nuclei for polar fusion.

Acknowledgement

I am indebted to Dr. L. B. Kajale for guidance and helpful criticism throughout the progress of this investigation.

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ESSENTIALITY OF TRACE ELEMENTS TO SOME SOIL FUNGI*

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Introduction

The status of trace elements in fungal metabolism underwent a most spectacular change when Steinberg (1919 *b*), in his epoch-making work, disproved Pfeffer's 'theory of chemical stimulation' and established, instead, the nature of some of them as essential nutrients for *Aspergillus niger*. Although their essentiality in plant nutrition has been claimed much earlier (Raulin, 1869; Bertrand, 1905, 1912), the idea was hardly accepted by plant physiologists of that time. Why this was so and how effectively the earlier theories and concepts, such as the 'Arndt-Schultz law', the 'oligodynamic effect' and the 'theory of chemical stimulation', held sway in those times are admirably described by Foster (1949). As a result of considerable work done during the past four decades in the field of plant as well as animal nutrition, trace elements are now looked upon, not as spurious 'stimulants', but as biologically essential nutrients.

Since Steinberg's classical research, there has been an increased interest in the trace element nutrition of fungi, though the number of species studied under strict conditions with regard to essentiality is surprisingly small. The literature on this subject is vast and often conflicting. Extensive reviews and comprehensive accounts of such work have been furnished by Steinberg (1939, 1950 *b*), Foster (1939, 1949), Perlman (1949), Hawker (1950) and Lilly and Barnett (1951).

Results of investigations on the essentiality of Fe, Zn and Cu to some soil *Fusarium* species, grown under rigorously controlled conditions, are described in this communication. The studies formed part of the general layout of work on certain vascular fusarioses that have been receiving considerable attention in this laboratory (*cf.* Sadasivan, 1958).

Materials and Methods

Securing a set of experimental conditions tested and proved to be of a sufficient degree of purity is an essential pre-requisite in studies designed to evaluate the indispensability of trace elements. It is now well recognized that such studies demand rigorously controlled conditions. The problems involved in such work have been reviewed and

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* Formed part of the author's Doctoral Thesis, University of Madras.

discussed by the author in an earlier communication (Saraswathi-Devi, 1958). In the present work, the techniques followed were as standardized in this laboratory, adopting the very sensitive biological test to evaluate their efficiency (Saraswathi-Devi, 1954). The experimental conditions and set up were the same as described therein.

Organisms.—Nine species of *Fusarium*, *viz.*, *F. vasinfectum* Atk., *F. moniliforme* Sheld., *F. udum* Butl., *F. scirpi* Lam *et* Pantr., *F. orthoceras* App. *et* Wr., *F. oxysporum* Schl., *F. lini* Bolley, *F. poæ* (Pk.) Wr. and a species of *Fusarium*, isolated from wilted tomato plants, were used.

Inoculum and incubation.—The aerial growths from week-old nutrient-agar slant cultures were scraped off without adhering agar particles, using a sterile platinum wire, and suspended in 5 ml. of sterile water blanks. Three drops of this spore-mycelial suspension were used per flask. All cultures were incubated in the dark at laboratory temperature (28–31° C.). Growth was measured by the dry weight method.

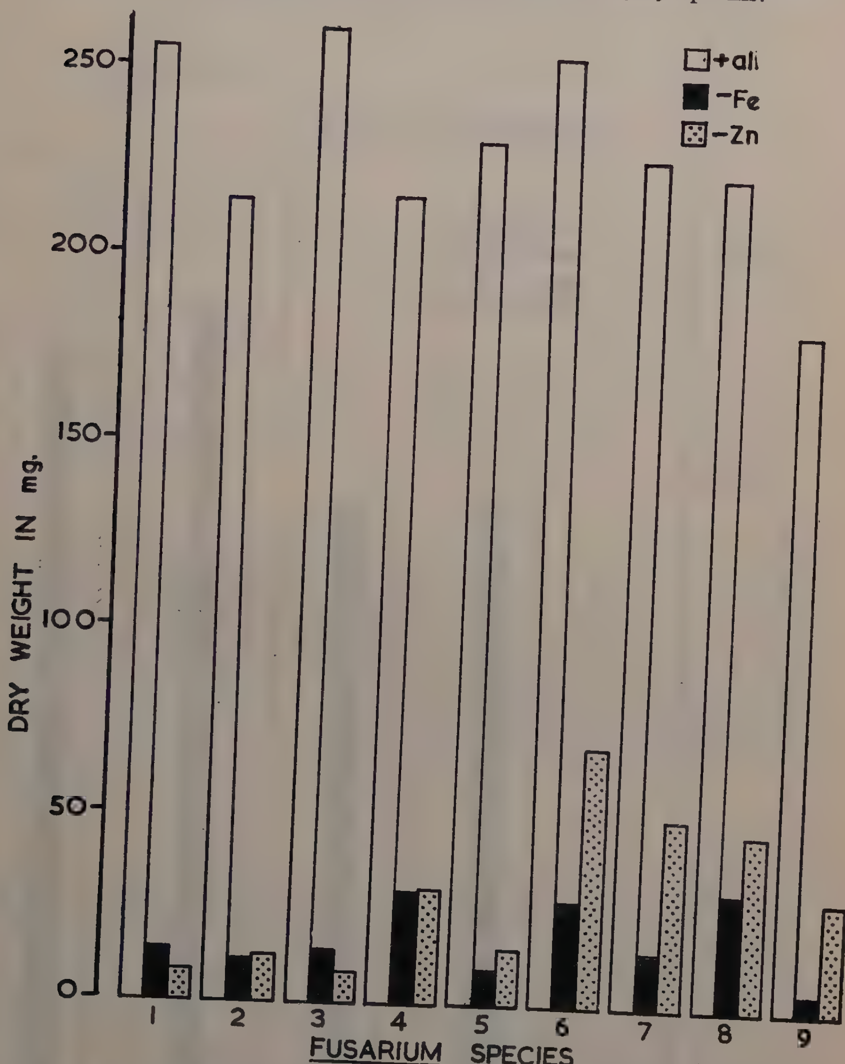
EXPERIMENTAL

Experiment 1: *Detecting the essentiality of Fe and Zn for normal growth of nine species of* Fusarium.—The experiment was split up into two batches for convenient handling. The Al_2O_3 method of purification of basal medium was employed. Culture vessels used were 'Hysil' brand (500 ml. conical flasks and 100 ml. beakers to cover). The purified basal medium was adjusted to pH 5·0 before autoclaving. The three trace element stock solutions were '+ all' (containing Fe, Zn, Cu, Mn and Mo, the generally recognized micronutrients), '− Fe' and '− Zn'. The cultures in batch '*a*' were run in quintuplicates and those in batch '*b*', in quadruplicates. All cultures were incubated for 14 days.

Results taken on the 15th day of incubation are presented in Plate XXV, Figs. 1–4, Table I and Text-Fig. 1, which show the nature and amount of growth of the organisms studied in the different media. It is evident that in the absence of either Fe or Zn growth was limited to a great extent, in some cases falling to 3% of that in the complete medium. In most only thin wefts of submerged hyphæ were formed in the deficient media as against the thick surface mat produced in the complete medium. The results show the indispensability of the two elements for normal growth of these species.

Experiment 2: *Detecting the essentiality of Cu for normal growth of four species of* Fusarium.—It is generally conceded that deficiency studies with Cu are more difficult than those with Fe or Zn (Lilly and Barnett, 1951), since this element is usually needed only in much smaller amounts than the latter two. From repeated tests with the standard 'M' strain of *Aspergillus niger*, during standardization of techniques, it was found by the author that variations in the degree to which an element was removed in the different trials were greater in the case of Cu than that of Fe or Zn where they were negligible. Hence, in studies with

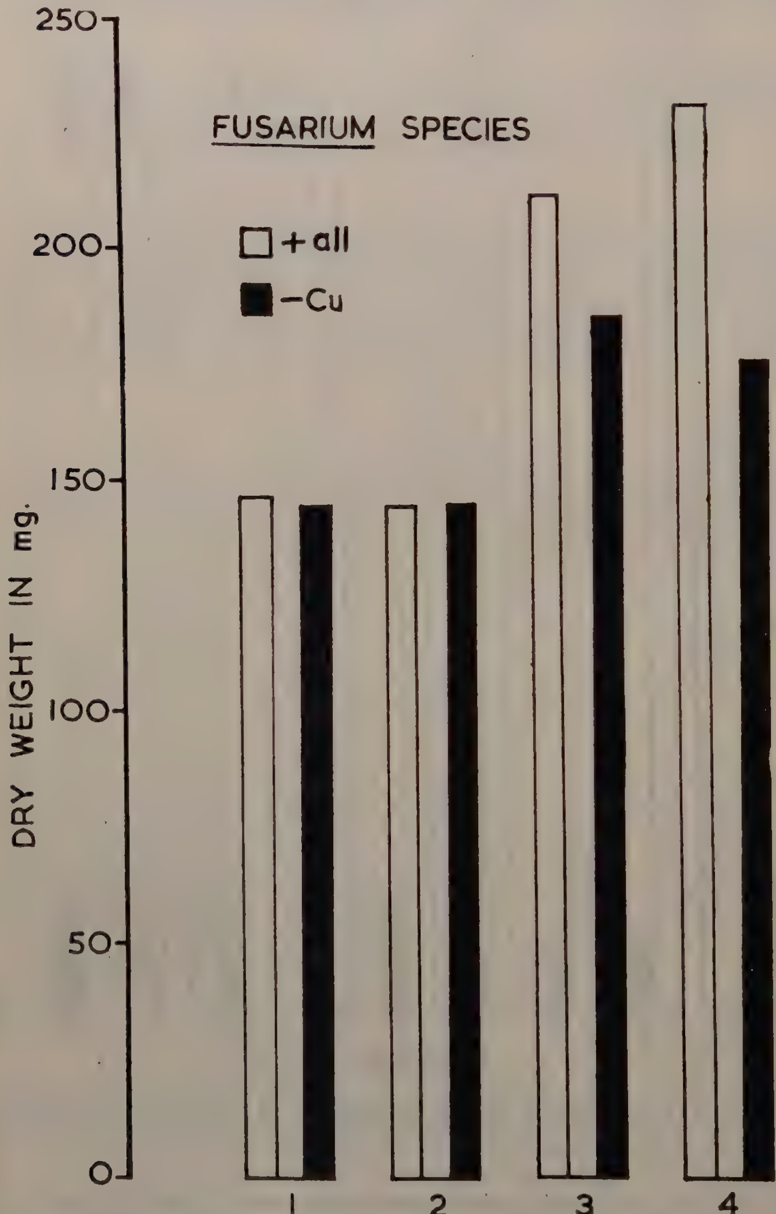
Cu, the standard test organism was grown alongside the fungi of interest, in the same batch of medium, and results were taken as satisfactory only where the test fungus showed typical deficiency symptoms.



TEXT-FIG. 1. Showing the dry weight yields of nine species of *Fusarium* in complete, Fe-deficient and Zn-deficient media. (For details of *Fusarium* spp. 1 to 9, please see Table I.)

The H_2S co-precipitation method as used for the removal of Mo was adopted as such for purification of the basal medium. The culture vessels used were of 'Pyrex' brand. The trace element stocks used

were '+ all' and '– Cu'. The cultures were run in quadruplicates. Other experimental conditions were as in Experiment 1.



TEXT-FIG. 2. Showing the dry weight yields of (1) *F. vasinfectum*, (2) *F. moniliforme*, (3) *F. udum* and (4) *F. lini* in complete and Cu-deficient media.

TABLE I

Showing the percentages of growth of 9 species of Fusarium *in complete and trace element deficient cultures*

Organism used	'+ all'	'— Fe'	'— Zn'
Batch '*a*':			
1. *Fusarium vasinfectum* ..	100 (254·6 mg.)	5	3
2. *F. moniliforme* ..	100 (216·2 mg.)	5	5
3. *F. udum* ..	100 (262·1 mg.)	5	3
4. *F. scirpi* ..	100 (217·6 mg.)	14	14
5. *Fusarium* sp. ..	100 (238·2 mg.)	4	7
Batch '*b*':			
6. *F. orthoceras* ..	100 (257·1 mg.)	11	27
7. *F. lini* ..	100 (229·9 mg.)	7	42
8. *F. oxysporum* ..	100 (224·6 mg.)	15	20
9. *F. poæ* ..	100 (183·5 mg.)	3	17

Text-Figure 2 shows the amount of growth of the four species of *Fusarium* in complete and Cu-deficient media. The response of the test organism in similar media is shown in Plate XXV, Fig. 5. The fungal mat formed was thin and completely sterile, which are the typical Cu-deficiency symptoms (*cf.* Nicholas and Fielding, 1951, Plate III, *a*, *b*, *c*). This indicated that traces of Cu have been satisfactorily removed from the medium supplied. Under these conditions, there was no appreciable reduction in growth of the *Fusarium* species studied in the absence of Cu, showing thereby that none of them needed more than very small traces of this element for normal growth.

DISCUSSION

From the essentiality point of view, growth and/or sporulation—the most obvious responses of fungi—have been the first considered criteria. If the element concerned is essential, there should be a significant difference in response between the deficient and supplemented cultures (Foster, 1949). The drastic reduction in growth obtained here in the Fe- and Zn-deficient cultures clearly indicate how indispensable these two elements are for normal growth of the *Fusarium* species studied. This marked reduction is the most outstanding characteristic of Fe and Zn deficiencies (Lilly and Barnett, 1951; Nicholas and Fielding, 1951).

In contrast to this, the species tried did not show any appreciable decrease in growth in the Cu-omitted cultures. The growth ratios,

$$\frac{\text{Dry weight produced in the presence of the element}}{\text{Dry weight produced in the absence of the element}}$$

(Steinberg, 1935), were unity in the case of *F. vasinfectum* and *F. moniliforme*. *Fusarium udum* and *F. lini* showed but negligible decrease in growth. Although Cu-deficiency did not reduce growth to the same extent as Fe or Zn deficiency, considerable reduction was noticed in Cu-omitted cultures of the test organism (*cf.* Saraswathi-Devi, 1954). The response of the *Fusarium* species in the Cu-deficient medium (Text-Fig. 2) where the standard strain showed very characteristic deficiency symptoms (Plate XXV, Fig. 5) indicate that their need for this element is much smaller than that of the 'M' strain of *Aspergillus niger*. A much higher degree of removal of this element may be needed to demonstrate its essentiality to these species.

Since the standard of the conditions under which different organisms have been shown to require certain trace elements (Roberg, 1928; McHargue and Calfee, 1931; Ledeboer, 1934; Mosher *et al.*, 1936; Rogers, 1938; Blank, 1941; Ezekiel, 1945) does not seem to have been critically ascertained, the results of the present investigations are compared to that with the 'M' strain, of known requirements, grown under similar environmental conditions. Steinburg (1950 *a*), studying certain fungal pathogens of tobacco, grown along with his strain of *Aspergillus niger*, noted them to have much the same needs as the *A. niger* strain for Fe, Zn, Cu, Mn and Mo.

The percentages of growth in the deficient media varied with the species. This was not unexpected, since even strains of the same species are known to vary in their response to similar deficient media (Steinberg, 1919 *a*; Nicholas, 1952; Saraswathi-Devi, 1954). Indeed, variation, rather than uniformity, in nutritional requirements is more the rule than exception among organisms (Lilly and Barnett, 1951). This, however, might be a reflection on the actual requirements of the various organisms for the elements concerned, the species showing a greater reduction having a larger need than those showing less, under identical conditions.

The little amount of growth obtained in the Fe- and Zn-deficient cultures was due to the presence of these elements in minute traces, even after purification. This is an indication of the practical difficulty in ridding the culture solution completely of trace element impurities.

Summary

The essentiality of Fe, Zn and Cu for some species of *Fusarium* has been investigated under rigorously controlled conditions that have been proved to be satisfactory for such studies, using the very sensitive biological test.

Under these conditions, the essentiality of Fe and Zn to the species studied was proved. On the other hand, the indispensability of Cu could not be demonstrated even where the standard test organism produced the typical deficiency symptoms. The *Fusarium* species studied appeared to need Cu only in much smaller amounts than the test organism.

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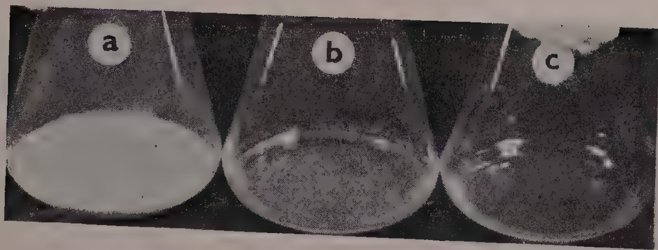

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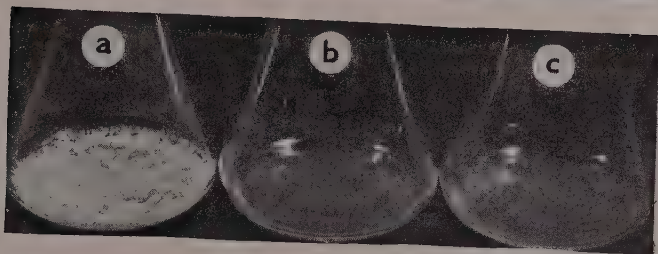

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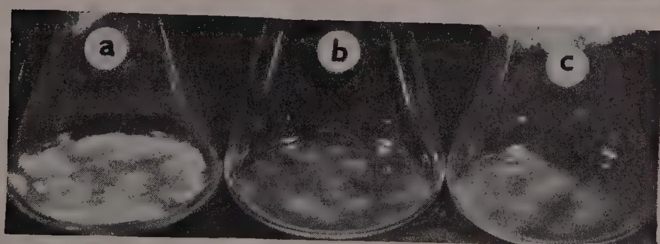

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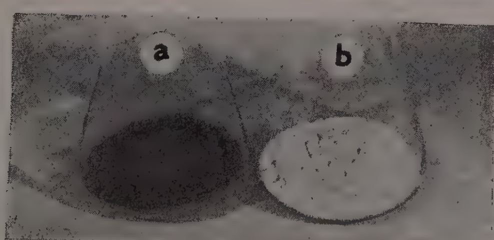

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L. Saraswathi-Devi

FLORAL ANATOMY OF SIMARUBACEÆ—I

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INTRODUCTION

THE family Simarubaceæ comprises of 32 genera and 200 species (Lawrence, 1951). It is placed in the order Geraniales by Bentham and Hooker (1862–93) and by Engler and Prantl (1931). Rendle (1938) and Hutchinson (1926) included the family in the order Rutales along with the other closely allied families like Rutaceæ, Burseraceæ and Meliaceæ. The family Meliaceæ, however, is placed in a separate order, Meliales, by Hutchinson (1926).

Our knowledge of floral anatomy in the family is limited to the study of only two species, namely, *Quassia amara* and *Ailanthus glandulosa* by Saunders (1939), who was more engrossed in supporting her theory of carpel polymorphism. Recently Nair (1956) studied the floral anatomy and embryology of *Balanites roxburghii* which is included in Zygophyllaceæ by Engler and Prantl (1931) and in Simarubaceæ by Bentham and Hooker (1862–93).

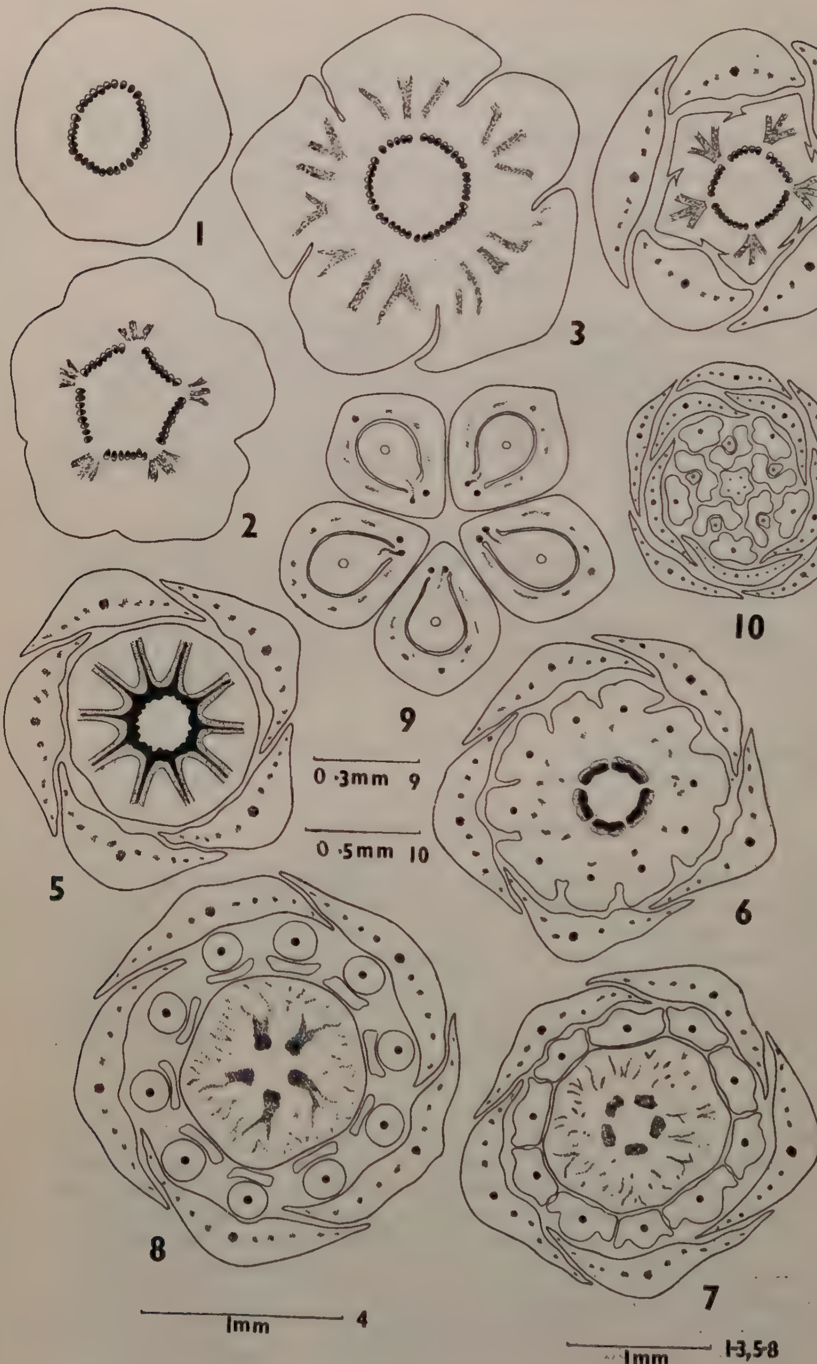
The present paper deals with the floral anatomy of *Quassia amara* L. and *Ailanthus excelsa* Roxb.

MATERIALS AND METHODS

The material of *Quassia amara* was collected from a tree in the garden attached to the Church at Yanam and the material of *Ailanthus excelsa* was collected from trees growing locally at Waltair. Both the materials were fixed in F.A.A. Customary methods of dehydration, infiltration and embedding were followed. Serial transverse sections of flower-buds of different ages were cut at a thickness of 8–12 μ and the sections were stained in crystal violet using erythrosin as counter stain.

OBSERVATIONS

Quassia amara.—The flower in *Quassia amara* is bisexual, regular and heterochlamydeous. The perianth is represented by two pentamerous whorls. The andrœcium consists of ten stamens of two different heights, the five an antipetalous ones being shorter than the antisepalous ones. The stamens bear appendages which are united to their bases for some distance (Text-Figs. 7 and 8). The gynœcium is represented by five apocarpous pistils, each bearing a single ovule. The style, however, is single and shows five strands of conducting tissue (Text-Fig. 10). A massive disc is present between the andrœcium and the gynœcium.



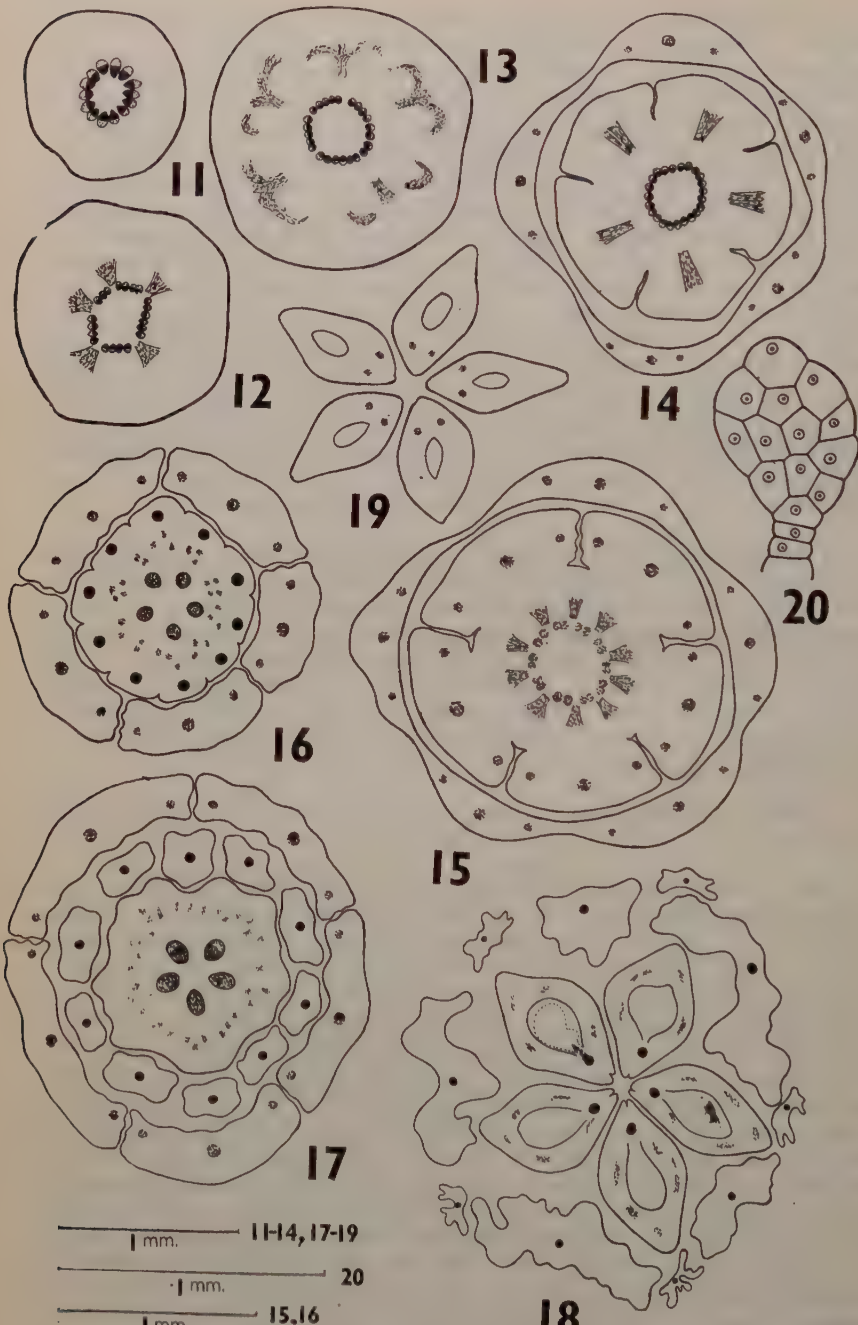
TEXT-FIGS. 1–10. *Quassia amara.* For explanation see text.

The pedicel in its structure shows a ring of closely placed vascular bundles (Text-Fig. 1). Connected with the stele are traces that supply the sepals (Text-Figs. 2 and 3). Higher up five petal traces arise (Text-Fig. 4). The traces supplying the perianth members divide and form numerous small branches in the respective organs (Text-Figs. 4–8 and 10). Next, the traces for the ten stamens are recognised in one whorl (Text-Fig. 5). The staminal traces as they proceed towards the periphery give off a few strands which feed the disc (Text-Fig. 6). Numerous branches which feed the disc arise from the bundles of the main stele after the staminal supply is organised (Text-Figs. 7 and 8). Higher up five dorsal carpellary traces are demarcated from the five bundles of the main stele (Text-Fig. 8) and these branch forming smaller bundles (Text-Fig. 8). After the dorsal carpellary traces are demarcated the main stele forms five pairs of ventrals which do not fuse (Text-Fig. 9). The ovule in each carpel receives its supply from one of the ventrals (Text-Fig. 9) while the other continues into the style. Thus, the style shows five strands of conducting tissue (Text-Fig. 10). Small branches arise from the ventral bundles and these supply the wall of the ovary (Text-Fig. 9). These branches, however, fade away towards the top of the ovary.

Ailanthus excelsa.—The flowers are pentamerous and are unisexual by reduction. What appear to be bisexual flowers are only functionally female, the stamens being modified into petaloid staminodes, of which the antipetalous ones are much smaller (Text-Fig. 18). The gynœcium is represented by five apocarpous pistils each with a single ovule. The styles are connate and the stigmas are free. In the functionally male flowers, there is a rudiment of the ovary in the centre. In these sometimes one or more of the stamens become abortive. A disc is present between the andrœcium and gynœcium.

Numerous multicellular hairs (Text-Fig. 20) are present on the gynœcium.

The pedicel shows a ring of vascular bundles (Text-Fig. 11). Connected with the main stele are five traces which supply the sepals (Text-Fig. 12). Each of these divides to form the laterals as they enter the base of the calyx (Text-Fig. 13). Next the traces for the five petals arise (Text-Fig. 14). The traces supplying the perianth parts divide to form smaller bundles in the respective organs (Text-Figs. 14–17). After the perianth supply is given off, the traces for the ten stamens arise in one whorl (Text-Fig. 15). In the functionally female flowers these traces supply the staminodes (Text-Fig. 18). The staminal traces as they proceed towards the periphery give off a few branches which feed the disc (Text-Figs. 16 and 17). The remaining part of the stele becomes organised into five bundles and these form the ovarian supply (Text-Figs. 16 and 17). No dorsal carpellary traces are organised. The ventral bundles after supplying the ovules divide into two each (Text-Figs. 18 and 19) and these continue into the styles and stigmas. Branches which supply the wall of the ovary are given out by the ventrals (Text-Fig. 18). In the functionally male flowers the main stele is almost completely used in the formation of the staminal supply.



TEXT-FIGS. 11–20. *Ailanthus excelsa.* For explanation see text.

Discussion

A study of floral anatomy of *Balanites roxburghii* (Nair, 1956), *Quassia amara* and *Ailanthus excelsa* reveals the tendency of the flower to become unisexual. Occurrence of polygamous flowers has been reported in *Ailanthus glandulosa* by Saunders (1930).

The sepals in *Quassia* and *Balanites* (Nair, 1956) receive three traces each. In *Ailanthus*, however, the sepals receive only a single trace each.

The petals in *Quassia*, *Ailanthus* and *Balanites* (Nair, 1956) receive only a single trace. In *Ailanthus glandulosa* (Saunders, 1939) the traces for the antepetalous stamens and petal midribs arise conjointly.

The obdiplostemonous condition of the andrœcium is emphasised only in *Ailanthus glandulosa* (Saunders, 1939) where the antepetalous staminal traces arising conjointly with the petal midribs become detached earlier. In *Balanites* (Nair, 1956) the traces for the ten stamens arise in two whorls as in *Ailanthus glandulosa* (Saunders, 1939) but here the traces for the antisepalous stamens are first demarcated. In *Quassia amara* and *Ailanthus excelsa* the traces for the ten stamens arise in one whorl independently from the main stele. This condition might have arisen by the suppression of the internode between the two whorls of stamens.

A disc is present in all the species investigated. It is very greatly developed in *Quassia* and *Balanites* (Nair, 1956). In species of *Ailanthus* it is not so well pronounced. The disc in all the species is fed by branches given off from the staminal traces. In *Quassia*, however, the disc in addition receives branches from the bundles of the main stele. It may be mentioned here that the disc in Meliaceæ is also supplied by branches derived from the staminal traces (Narayana, 1958 *a* & *b*).

The gynœcium is apocarpous except in *Balanites* (Nair, 1956) where it is syncarpous. According to Saunders (1939) the ovary in *Quassia* and *Ailanthus glandulosa* is only pseudoapocarpous, the condition having arisen as a result of median radial splitting of "fertile carpels". Thus, according to her each ovary in them consists of a sterile carpel flanked on either side by half the neighbouring fertile carpel ($\frac{1}{2}$ 1 $\frac{1}{2}$). Dorsal carpellary traces are demarcated in *Quassia* and *Balanites* (Nair, 1956) while, in *Ailanthus excelsa* and *Ailanthus glandulosa* (Saunders, 1939) they are not demarcated. The dorsal carpellary traces in *Quassia* divide to form several branches which fade away in the receptacle while in *Balanites* (Nair, 1956) each dorsal carpellary trace divides into three, a median and two laterals. The latter and the fused secondary marginals arising later supply the ovary wall. In *Quassia* and *Ailanthus* the wall of the ovary is supplied by branches derived from the ventral bundles. Similar branches arising from the ventrals have been reported in Meliaceæ (Narayana, 1958 *a* and 1958 *b*). The ventrals in *Quassia* remain free. One of them supplies the ovule and the other continues into the style. However, the ovary wall is supplied by

branches arising from both the ventrals. In *Ailanthus excelsa* the ventral bundle supplies the ovary wall and the single ovule. After giving the ovular supply it divides into two and these continue into the style and stigma. In *Balanites* (Nair, 1956) the dorsals, the median dorsals, and the placental bundles constitute the stylar supply.

Summary

The floral anatomy of *Quassia amara* and *Ailanthus excelsa* has been studied.

The flower in *Quassia* is pentamerous and bisexual. In *Ailanthus*, however, the flowers become unisexual by reduction.

The sepals in *Quassia* receive three traces each while in *Ailanthus* they are single traced. The petals in both genera are single traced. The traces supplying the perianth divide to form smaller bundles in the respective organs.

The traces for the stamens arise in one whorl. The stamens in *Quassia* bear appendages which are united to their bases for some distance. In *Ailanthus* the staminodes retain the vascular supply.

The disc in *Quassia* is very massive. It is supplied by the branches given off by the staminal traces and also by the branches arising from the main stele. In *Ailanthus*, however, the disc receives only branches given off by the staminal traces.

The ovary in both the genera consists of five apocarpous pistils with a single ovule in each. Dorsal carpellary traces are demarcated only in *Quassia*. The ovary wall is supplied by branches arising from the ventral bundles. Both the ventrals continue into the style and stigma in *Ailanthus* while in *Quassia* only one of the two ventrals continues to the top of the style, the other being used in the ovular supply.

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